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Remote substituent effect favoring the formation of *syn*-adducts in the chelation controlled radical reactions of γ-benzyloxy-α-methylenecarboxylic acid esters

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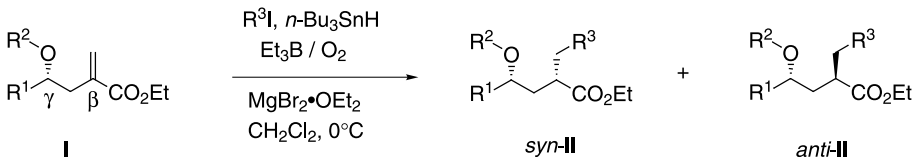
Abstract—The chelation controlled radical reactions of ethyl γ-benzyloxy-α-methylenecarboxylates bearing a bulky γ-substituent, such as $CHMe_2$, $CHPh_2$, *c*-C_6H_{11} and CH(Ph)OTBDMS, with alkyl iodides gave the *syn*-adducts with high diastereoselectivities. However, the diastereoselectivity for the substrates bearing a γ-substituent CH(*i*-Pr)OTBDMS depended critically on the configuration of the substituent; the substrate bearing the OTBDMS group *anti* to the γ-benzyloxy group showed poor diastereoselectivity, but its diastereomer gave *syn*-adduct exclusively. The high *syn*-selectivitiy is referred to the H-atom transfer to the outside face of radical center in the sharply folded seven-membered chelate intermediate bearing the ethoxy group with *Z*-geometry. The corner flapping of the radical center atom of the global minimum energy conformer generates a local minimum conformer and the H-atom transfer to the outside face of the radical center of the newly formed structure gives the *anti*-adduct. The poor diastereoselectivity is due to the very small energy difference between the two conformers and consequently both the *syn*- and *anti*-adducts are yielded in nearly equal amounts.

1. Introduction

During the past decade the stereochemical control of acyclic radical reactions has been received considerable attention and significant levels of diastereoselectivity have been achieved when they adopt preferred conformations.[1] The use of Lewis acids offers the possibility to regulate conformations and improve the stereoselectivity in acyclic radical reactions.[2] The bulk of substituents at the stereogenic center is, as well, an important factor controlling the stereoselectivity as represented by the exocyclic effect in 1,2-asymmetric induction.[3]

We have recently reported the chelation-controlled 1,3-asymmetric induction in the radical-mediated additions to α-methylene-γ-oxycarboxylic acid esters **I** (Scheme 1).[4,5] The diastereoselectivity depended on the substituents R^1 and R^2 and the alkyl iodides R^3I. The radical reactions of γ-hydroxy, γ-methoxy and γ-methoymethoxy esters with methyl, ethyl or isopropyl iodide (R^3=Me, Et or *i*-Pr) performed in the presence of Lewis acid gave *syn*-**II** predominantly. In the addition of bulky *tert*-butyl radical, however, the selectivity was reversed and the major product was *anti*-**II**. In contrast to the substrates mentioned above, γ-benzyloxy esters **I** (R^2=Bn) showed *syn*-selectivity irrespective of the bulk of alkyl iodides. Furthermore, we have reported the origin of diastereoselectivities based on the conformational analysis of the chelated radical intermediates obtained by combination of CONFLEX and PM3 calculations.[4d,6] The H-atom transfer reaction to the sharply folded seven-membered chelate intermediate[4d,7,8] bearing an ethoxy group with *Z*-geometry (dihedral angle O=C–O–C of ester moiety: ca. 0°) and CH_2–R^3 bond parallel to the radical face occurs exclusively on the exposed outside face of radical center to afford the highest *syn*-selectivity.



Scheme 1. Radical reactions of α-methylene-γ-oxycarboxylic acid esters **I** with alkyl iodides.

Keywords: radical reaction; 1,3-asymmetric induction; remote substituent effect; Lewis acid; CONFLEX-PM3.

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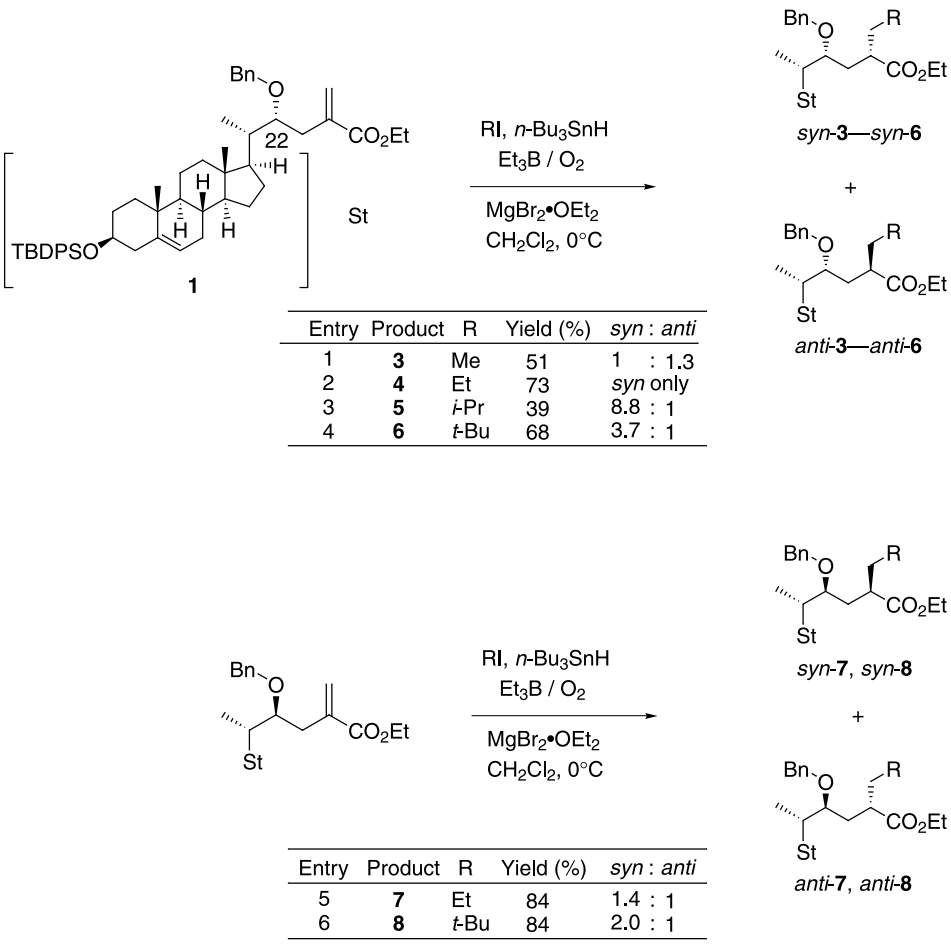


Entry	Product	R	Yield (%)	*syn* : *anti*
1	**3**	Me	51	1 : 1.3
2	**4**	Et	73	*syn* only
3	**5**	*i*-Pr	39	8.8 : 1
4	**6**	*t*-Bu	68	3.7 : 1

Entry	Product	R	Yield (%)	*syn* : *anti*
5	**7**	Et	84	1.4 : 1
6	**8**	*t*-Bu	84	2.0 : 1

Scheme 2.

In the radical reactions of the steroidal γ-benzyloxy-α-methylenecarboxylic acid esters **1** and **2** with alkyl iodides R^3I performed in the presence of $MgB_2{\cdot}OEt_2$, we have observed that the diastereoselectivity depends on the configuration at C-22 (i.e. the relative stereochemistry of γ- and δ-substituents) and the bulk of R^3 group (Scheme 2).[4c,d] The results suggest that there may exist stereochemical relationships between the γ- and δ-substituents that exert either complementary or opposing influences on the facial bias of the radical center.

We report herein the effect of substituents at the δ-position and their configurations affecting the diastereoselectivity in the chelation controlled radical addition reactions to γ-benzyloxy-α-methylenecarboxylic acid esters **8**, **9** and **15**–**25** (Scheme 4 and Tables 1 and 2). This work was performed to find out the radical reactions with reliably high level of diastereoselectivity.

Table 1. Diastereoselectivity in the radical reactions of α-methylene-γ-benzyloxycarboxylic acid esters **9** and **10** with isopropyl or *t*-butyl iodide in the presence of $MgBr_2{\cdot}OEt_2$

Entry	Substrate	R′	Product	Yield (%)	*syn*:*anti*
1	**9**	*i*-Pr	**11**	88	>50:1
2	**9**	*t*-Bu	**12**	99	7.6:1
3	**10**	*i*-Pr	**13**	100	>50:1
4	**10**	*t*-Bu	**14**	97	9.2:1

2. Results and discussion

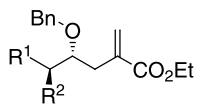
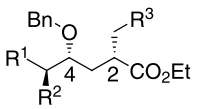
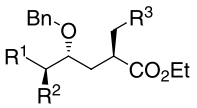
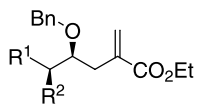
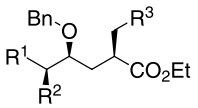
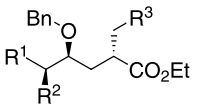
2.1. Preparations of the substrates 9, 10 and 15–25

2.1.1. Preparation of 9, 10 and 15–17. Substrates **9** and **10** were prepared from octanal and ethyl 2-(bromomethyl)propenoate following the procedures reported previously.[4d] Substrates **15**–**17** were prepared from isobutyl aldehyde, diphenylacetaldehyde, and cyclohexylcarbaldehyde, respectively, following the procedures reported previously.[4c]

2.1.2. Preparation of 18 and 22. The alcohol **46**[9] was transformed to the silyl ether **47** with *tert*-butyldimethylsilyl chloride and imidazole in 47% yield (Scheme 3). The oxidative cleavage of the thioacetal **47** with *N*-bromosuccimide in acetone gave the aldehyde **52** in 77% yield.[10] The Reformatsky reaction of the aldehyde with ethyl 2-(bromomethyl)propenoate and zinc[11] gave the hydroxy esters **56** and **57** in 81% yield with 3.3:1 diastereomer ratio.[12] The benzylation of the alcohols **56** and **57** with benzyl 2,2,2-trichloroacetimidate and trifluoromethanesulfonic acid gave the benzyl ethers **18** (87% yield) and **22** (62% yield), respectively.[13]

2.1.3. Preparation of 19 and 23. Usual treatment of the alcohol **48**[9] with *tert*-butyldimethylsilyl chloride and imidazole gave the silyl ether **49** in 99% yield. The

Table 2. Diastereoselectivity in the radical reactions of α-methylene-γ-oxycarboxylic acid esters **15**–**25** with alkyl iodides R^3I in the presence of $MgBr_2{\cdot}OEt_2$

Entry	Substrate	R^1	R^2	Product	R^3	Yield (%)	*syn*:*anti*[a]
							
	15–21 (*anti*)		**32–38** (2,4-*syn*)		**32–38** (2,4-*anti*)		
1	**15**	Me	Me	**26**	*i*-Pr	75	11:1
2	**15**			**27**	*t*-Bu	67	3.7:1
3	**16**	Ph	Ph	**28**	Et	82	18:1
4	**16**			**29**	*i*-Pr	88	>50:1
5	**17**	$-CH_2(CH_2)_3CH_2-$		**30**	Et	98	17:1
6	**17**			**31**	*i*-Pr	92	40:1
7	**18**	*i*-Pr	OTBDMS	**32**	*i*-Pr	94	1.2:1
8	**19**	Ph	OTBDMS	**33**	Me	66	19:1
9	**19**			**34**	Et	93	35:1
10[b]	**19**			**35**	*i*-Pr	87	50:1
11	**19**			**36**	*t*-Bu	86	>50:1
12[c]	**20**	Ph	OBn	**37**	*i*-Pr	90	10:1
13[d]	**21**	Ph	Ome	**38**	*i*-Pr	89	6.7:1
							
	22–25 (*syn*)		**39–45** (2,4-*syn*)		**39–45** (2,4-*anti*)		
14	**22**	*i*-Pr	OTBDMS	**39**	*i*-Pr	95	>50:1
15	**23**	Ph	OTBDMS	**40**	Me	54[e]	11.5:1
16	**23**			**41**	Et	95	24:1
17	**23**			**42**	*i*-Pr	87	>50:1
18	**23**			**43**	*t*-Bu	90	>50:1
19[c]	**24**	Ph	OBn	**44**	*i*-Pr	90	6.7:1
20[d]	**25**	Ph	OMe	**45**	*i*-Pr	89	9:1

R^3I (3 equiv.), *n*-Bu_3SnH (2 equiv.), Et_3B (1 equiv.), $MgBr_2{\cdot}OEt_2$ (3 equiv.), CH_2Cl_2, 0°C.
[a] *syn* and *anti* denote the diastereomers bearing the CH_2R^3 group *syn* and *anti* to the benzyloxy group, respectively.
[b] Without Lewis acid, 40% yield and *syn*/*anti*=1:1.
[c] Reaction performed for the mixture of **20** and **24**.
[d] Reaction performed for the mixture of **21** and **25**.
[e] Conversion yield 72%.

oxidative cleavage of the thioacetal **49** with *N*-bromosuccimide in acetone gave the aldehyde **53** in 89% yield.[10] The Reformatsky reaction of the aldehyde with ethyl 2-(bromomethyl)propenoate and zinc[11] gave the hydroxy esters **58** and **59** in 89% yield with 1.7:1 diastereomer ratio.[12] The benzylation of the alcohols **58** and **59** with benzyl 2,2,2-trichloroacetimidate and trifluoromethanesulfonic acid gave the benzyl ethers **19** (58% yield) and **23** (58% yield), respectively.[13]

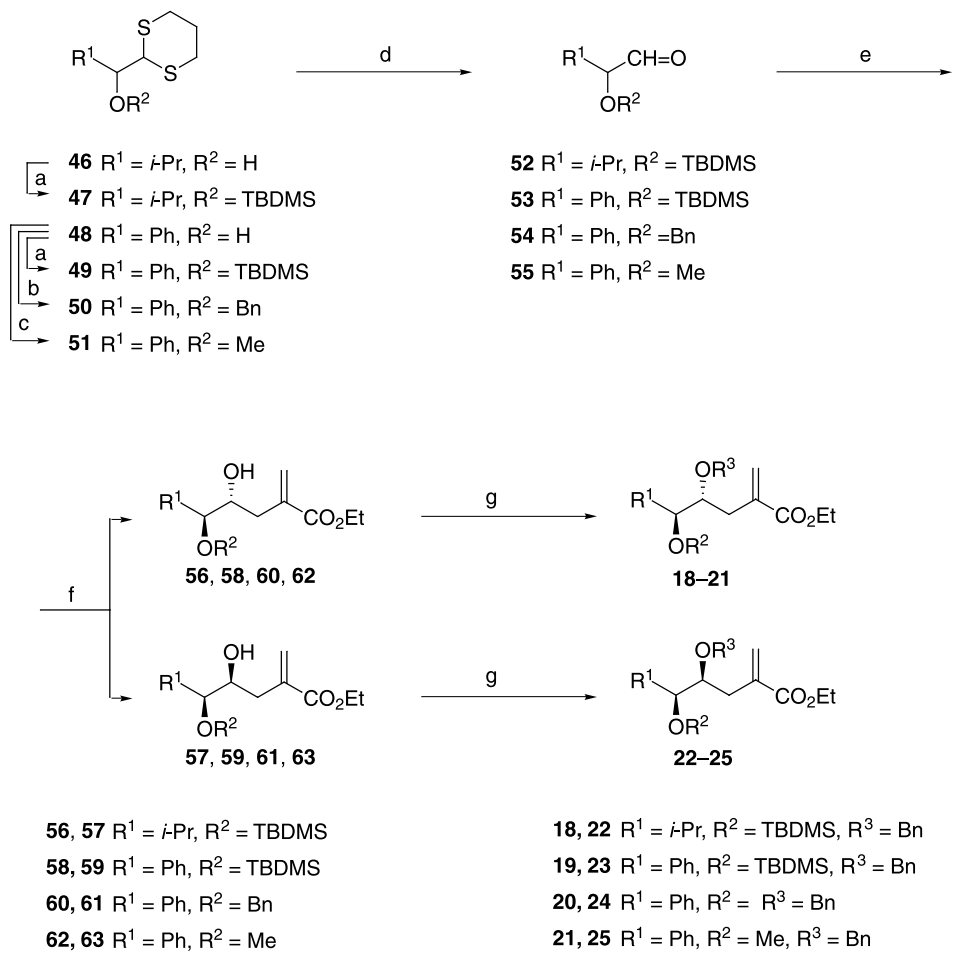
2.1.4. Preparation of 20 and 24. The benzylation of the alcohol **48**[9] with benzyl bromide and sodium hydride gave benzyl ether **50** in 73% yield. The benzyl ether was then transformed into the aldehyde **54** in 71% yield. The Reformatsky reaction of the aldehyde with ethyl 2-(bromomethyl)propenoate and zinc, followed by benzylation with benzyl 2,2,2-trichloroacetimidate and trifluoromethanesulfonic acid gave the bisbenzyl ether **20** and **24** as an inseparable mixture in 80% yield with 1.7:1 diastereomer ratio.[11–13]

2.1.5. Preparation of 21 and 25. The methylation of the alcohol **48**[9] with methyl iodide and sodium hydride gave methyl ether **51** in 70% yield. The ether **51** was then transformed into the aldehyde **55** in quantitative yield. The Reformatsky reaction of the aldehyde with ethyl 2-(bromomethyl)propenoate and zinc, followed by benzylation with benzyl 2,2,2-trichloroacetimidate and trifluoromethanesulfonic acid gave the esters **21** and **25** as an inseparable mixture in 25% yield (not optimized).[11–13]

2.2. Radical reactions

The reactions of γ-benzyloxy-α-methylenecarboxylic acid esters **9** and **10** bearing a bulky heptyl group on the γ-carbon atom with isopropyl iodide gave the *syn*-products exclusively, but the *syn*-selectivities in the reactions with *tert*-butyl iodide were lower probably because of the shielding of the radical face by the bulky *tert*-butyl group (Scheme 4 and Table 1). As we have previously reported,[4d] the diastereoselectivity of cyclohexyl ester **10** was higher than that of methyl ester **9** (entries 2 and 4).

In the case of ester **15** where both the substituents R^1 and R^2 were small methyl group, however, their selectivities were lower (Table 2, entries 1 and 2). For the substrates **16** and **17** with large δ-substituents extremely high *syn*-selectivities were attained (entries 3–6). We also examined the radical reactions of the esters **18** and **22** bearing a bulky *tert*-butyldimethylsiloxy and a smaller isopropyl groups at the



46 R^1 = *i*-Pr, R^2 = H
47 R^1 = *i*-Pr, R^2 = TBDMS
48 R^1 = Ph, R^2 = H
49 R^1 = Ph, R^2 = TBDMS
50 R^1 = Ph, R^2 = Bn
51 R^1 = Ph, R^2 = Me

52 R^1 = *i*-Pr, R^2 = TBDMS
53 R^1 = Ph, R^2 = TBDMS
54 R^1 = Ph, R^2 =Bn
55 R^1 = Ph, R^2 = Me

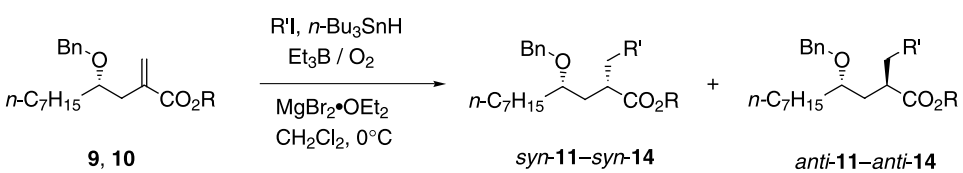
56, **57** R^1 = *i*-Pr, R^2 = TBDMS
58, 59 R^1 = Ph, R^2 = TBDMS
60, 61 R^1 = Ph, R^2 = Bn
62, 63 R^1 = Ph, R^2 = Me

18, 22 R^1 = *i*-Pr, R^2 = TBDMS, R^3 = Bn
19, 23 R^1 = Ph, R^2 = TBDMS, R^3 = Bn
20, 24 R^1 = Ph, R^2 = R^3 = Bn
21, 25 R^1 = Ph, R^2 = Me, R^3 = Bn

Scheme 3. Preparations of the α-methylene-γ-oxycarboxylic acid esters **18**–**25**. *Reagents*: (a) TBDMSCl, imidazole; (b) $PhCH_2Br$, NaH, THF; (c) CH_3I, NaH, THF; (d), NBS, $BaCO_3$, acetone; (e) $BrCH_2C(=CH_2)CO_2CH_2CH_3$, Zn, THF–$NH_4Cl$ aq., (f) separation of diastereomers **56**–**59** using SiO_2 chromatography; (g) $BnOC(=NH)CCl_3$, TfOH, cyclohexane–CH_2Cl_2.

δ-position. The reaction of **18** showed no diastereoselectivity, but its diastereomer **22** gave the diastereomer **39** bearing the β-$CH_2CH(CH_3)_2$ *syn* to the γ-benzyloxy group with excellent diastereoselectivity (entries 7 vs. 14). The configuration of the δ-substituents critically affects the diastereoselectivity in the reactions of esters **18** and **22** as well as the steroidal esters **1** and **2**. The stereochemistry of ester **22** with a smaller R^1=*i*-Pr and a larger R^2=OTBDMS corresponds to that of **1** with a small R^1=Me and a large R^2=St. The radical reactions of γ-benzyloxy-α-methylenecarboxylic acid esters **19** and **23** bearing two bulky groups (R^1=phenyl and R^2=OTBDMS) at the δ-carbon atom showed extremely high *syn*-selectivities (entries 8–11 and 15–18). The reactions were *syn*-selective irrespective of the bulk of alkyl R^3 groups and the selectivity increased in the order of Me, Et, *i*-Pr and *t*-Bu.

We carried out subsequently the radical reaction of the inseparable mixture of bisbenzyloxy esters **20** and **24** (diastereomer ratio 1.7:1) with isopropyl iodide in the presence of $MgBr_2{\cdot}OEt_2$. Among the four possible diastereomeric adducts **37** and **44**, two diastereomers bearing the isobutyl group *syn* to the benzyloxy group were obtained preferentially (entries 12 and 19), but the *syn*-selectivities



9, **10**

9 R = CH_3

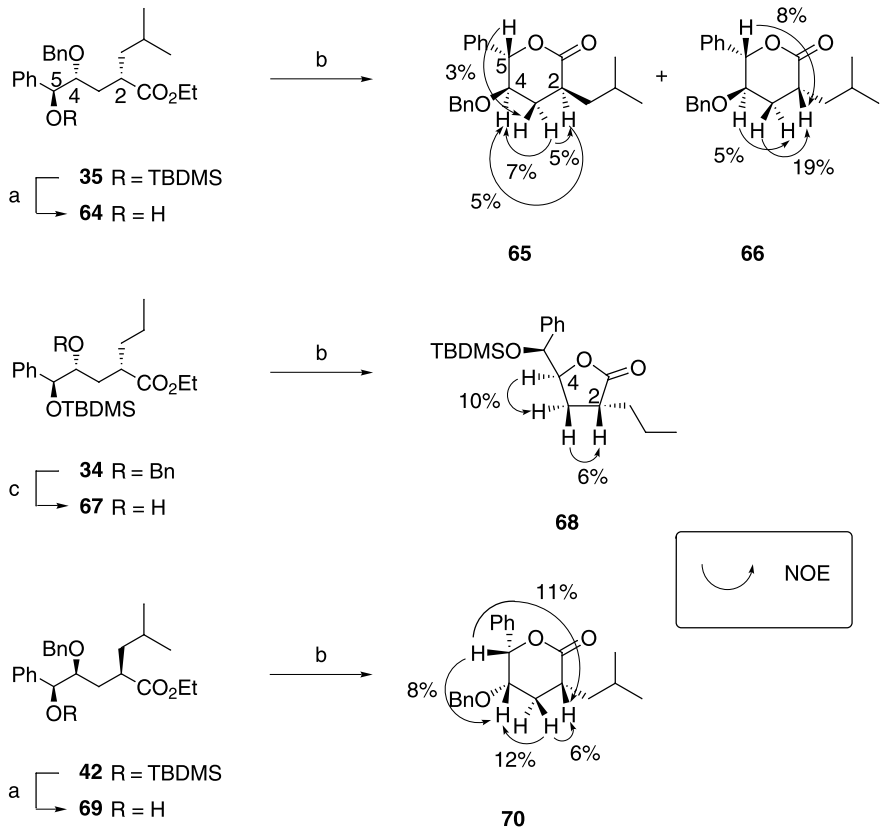
10 R = *c*-C_6H_{11}

syn-**11**–*syn*-**14**

anti-**11**–*anti*-**14**

11 R' = *i*-Pr
12 R' = *t*-Bu
13 R' = *i*-Pr
14 R' = *t*-Bu

Scheme 4.



Scheme 5. Determination of the stereochemistry of **34**, **35** and **42**. *Reagents*: (a) *n*-Bu_4NF, THF; (b) *p*-TsOH, benzene; (c) H_2, Pd–C, ethanol.

were lower than those of **19** and **23**. The reaction of the γ-benzyloxy-δ-methoxy esters **21** and **25** with isopropyl iodide also gave predominantly *syn* adducts **38** and **45**, respectively (entries 13 and 20). In the case of the ester **25**, high *syn*-selectivity has been observed despite the presence of a small methoxy group as R^2 (entry 20). The five membered chelate ring formed by the coordination of δ-benzyloxy (or δ-methoxy) and γ-benzyloxy groups to a magnesium ion may attribute to the high *syn*-selectivities in the reactions of esters **20**, **21**, **24** and **25**.[3] The methyl and methoxymethyl ethers corresponding to the benzyl ethers **1**, **2**, **9** and **10** showed low *syn*-selectivities.[4a,c,d] This may be due to the lack of an oxygen function on the δ-carbon atom necessary for the chelate ring formation mentioned above.

2.3. Determination of the diastereomer ratios of products 11–14 and 26–45 and their stereochemistry

In order to determine the stereochemistry of the products, we attempted initially the transformation of the adduct **35** into the δ-lactone **65** via δ-hydroxy ester **64** (Scheme 5). However, the cleavage of the silyl ether with tetrabutylammonium fluoride gave the δ-hydroxy ester **64** accompanying the δ-lactone **65** and its epimer **66**. Treatment of the hydroxy ester **64** with *p*-toluenesulfonic acid gave the lactones **65** and **66**. The NOE difference spectra of the δ-lactones **65** and **66** established the 4,5-*anti* stereochemistry of **35**, but the distinction between the 2,4-*syn* and 2,4-*anti* diastereomers was not accomplished because of the epimerization during lactonization.

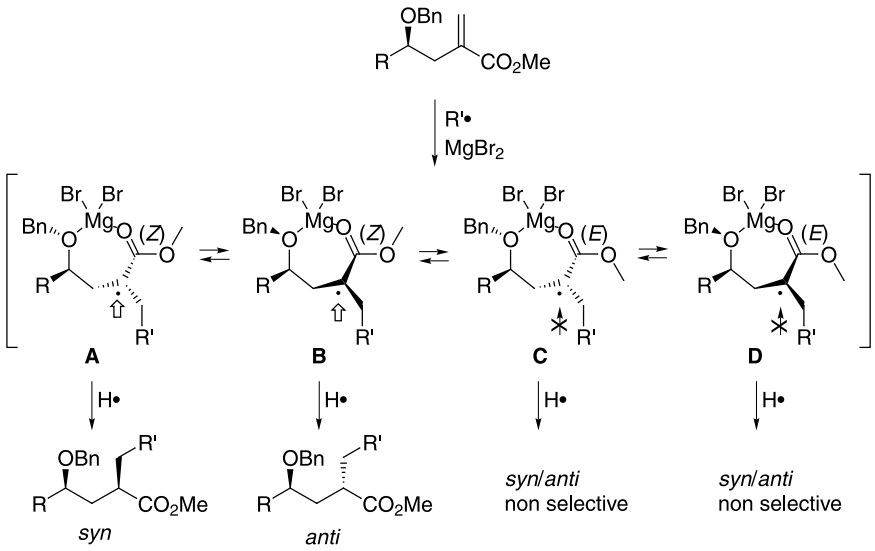
The adduct **34** was then transformed into the γ-lactone **68** via γ-hydroxy ester **67**. The NOE difference spectra showed the side chains are in *anti* relation, and consequently the 2,4-*syn* stereochemistry of **34** was established without ambiguity.

The transformation of the 4,5-*syn* diastereomer **42** into the corresponding δ-lactone **70** proceeded without epimerization. The 2,4-*syn* stereochemistry of **42** was assigned by the NOE difference spectra of **70**.

The NOE experiments suggest that the lactone **65** may adopt twist-chair conformation, and the lactones **66** and **70** may adopt twist-boat conformations. The exhaustive searches of low-energy conformers of the δ-lactones were performed with CONFLEX program using the MM2 force field for energy minimization.[6] The calculated global minimum energy structures of **65** and **70** agree to the NOE experiments. The calculations for **66** showed the presence of a twist-boat conformer, which is 0.2 kcal mol^{-1} higher in energy than the global minimum structure adopting a twist-chair conformation. The twist-boat conformer contributes probably to the NOE enhancement of α-H (8%) observed by irradiating δ-H.

The stereochemistries of the other products **11**–**14**, **26**–**33**, **36**–**41** and **43**–**45** were determined by comparing their chemical shifts of 2-H and 3-H with those of **34**, **35** and **42**.

The diastereomer ratios of the products were determined by the integrations of 2-H in the ^1H NMR spectra. The methine protons of 2,4-*syn*-adducts resonated in lower field than those of 2,4-*anti* adducts.[4]



Scheme 6. The structures of chelated radical intermediates **A**–**D** and their diastereoselectivities.

2.4. Origin of the diastereoselectivity

The diastereoselectivities in the chelation-controlled radical reactions of α-methylene-γ-oxycarboxylic acid esters have been rationalized based on the conformational analysis of the chelated transition state models **A**–**D** using CONFLEX and subsequent PM3 calculations (Scheme 6).[4d,7,8] The H-atom transfer reaction to the sharply folded seven-membered chelate model **A** bearing an ethoxy group with *Z*-geometry occurs on the exposed outside face of radical center to afford the *syn*-selectivity,[4d] whereas the H-atom transfer to the model **B** afford the *anti*-selectivity. The intermediate model **C** bearing a methoxy group with *E*-geometry shows poor diastereoselectivity due to the shielding of the radical face by the methoxy group.[4d]

To account for the experimental observations mentioned above, the conformational analyses of the radical intermediate models in the methyl radical addition to **15**, **18**, **19**, **22** and **23** were performed. To simplify the calculations, the ethoxy and *tert*-butyldimethylsilyl groups were replaced with methoxy and trimethylsilyl groups, respectively. In the case of ester **15**, the energy difference between the global minimum energy conformer **A** (R=$CHMe_2$) and the local minimum energy conformer **B** (R=$CHMe_2$) was 1.0 kcal mol^{-1} and the high *syn* selectivity (Table 2, entry 1) was attained. The extremely high *syn*-selectivity in the reaction of the ester **22** with isopropyl iodide (entry 14) can be referred to the geometry of the benzyl group shielding the inside radical face as well to the methoxy group with *Z*-geometry in the global minimum energy conformer **A-1** (Fig. 1, dihedral angle C1–C2–C1′–C2′=122.2°). The local minimum energy conformers **B** and **C** (R=CH(OTMS)*i*-Pr) were 3.8 and 2.9 kcal mol^{-1} higher in energy, respectively. The poor diastereoselectivities in the reactions of **1** (Scheme 2, entry 1) and **2** have been referred to the global minimum energy conformers **C** (R=St–CHMe) with *E*-geometry (calculated for ethyl esters),[4d] and not to the conformers **B** (R=St–CHMe) yielding *anti* adduct. However, in the case of the ester **18** (entry 7), the poor selectivity was found to be due to the low energy conformer **B** (R=CH(OTMS)*i*-Pr) being 0.3 kcal mol^{-1} higher in energy than the global minimum energy conformer **A** (R=CH(OTMS)*i*-Pr).

The PM3 calculations for the model of the ester **19** were abandoned because the CONFLEX calculations gave too many structures to be calculated. However, the conformational analysis of the intermediate model **A** (R=CH(OTMS)Ph) for the methyl radical addition to the ester **23** was achieved (entry 15). The global energy minimum conformer **A-2** bearing the methoxy group with *Z*-geometry (dihedral angle O=C–O–C of ester moiety:0.1°) showed that the H-atom transfer reaction proceeds exclusively on the exposed outside face of radical center to afford the high *syn*-selectivity (Fig. 1). The high diastereoselectivity in the reaction of **23** is furthermore referred to the geometry of the ethyl group attached to the radical center in **A-2** (dihedral angle C1–C2–C1′–C2′=−46.9°) where the ethyl group does not shield the outside face of radical center, despite the

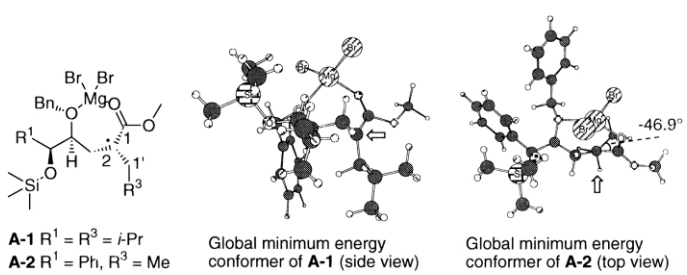


Figure 1. Global minimum energy conformers of the chelated radical intermediate models **A-1** and **A-2**.

presence of the local minimum energy conformer with *E*-geometry **C** (R=CH(OTMS)Ph; 0.7 kcal mol^{-1} higher in energy) inducing a poor diastereoselectivity.

The conformers **B** having a bulky R group (R=St–CHMe, *n*-C_7H_{15}, $CHPh_2$, CH*c*-C_6H_{11} or CH(OTMS)Ph) *syn* to the benzyl group may be disfavored because of the steric repulsion between the bulky substituents (R and BnO) oriented upward.

3. Conclusion

In summary, we have shown that the chelation controlled radical reactions of γ-benzyloxy-α-methylenecarboxylic acid esters bearing a bulky γ-substituent[14] with alkyl iodides gave the adducts with high *syn*-selectivities. The selectivity is referred to the H-atom transfer to the outside face of radical center in the sharply folded seven-membered chelate intermediate **A** bearing the ethoxy group with *Z*-geometry. However, the reaction of **18** showed poor diastereoselectivity despite the presence of a bulky γ-substituent. For the compounds **1** and **2**, the intermediate **C** bearing the ethoxy group with *E*-geometry shields the outside face of radical center and lowered the diastereoselectivity. In the reaction of **18**, however, the energy difference between the intermediates **A** and **B** was very small, and consequently both the *syn*- and *anti*-adducts were yielded in nearly equal amounts. The work described above emphasizes the possibility for attaining reliable radical mediated 1,3-asymmetric induction.

4. Experimental

4.1. General

^{1}H NMR spectra were recorded on a JEOL GSX-270 (270 MHz) or GSX-400 (400 MHz) spectrometer with $CDCl_3$ as the solvent and tetramethylsilane as an internal standard. ^{13}C NMR spectra were recorded on the instruments operating at 67.9 or 100.5 MHz with $CDCl_3$ as the solvent and internal standard (δ 77.0). Mass spectra (EI^+) were obtained on a JEOL JMS-700 mass spectrometer. Precoated Merck Kieselgel 60 F_{254} and Kanto silica gel 60 (spherical neutral) were used for thin layer chromatography and flash chromatography, respectively. All the products reported herein were colorless oils.

4.2. Preparation of the substrates 18–25

4.2.1. γ-Benzyloxy-α-methylene ester 9. ^{1}H NMR (400 MHz) δ 7.34–7.24 (5H, m, Ph), 6.20 (1H, d, *J*=1.2 Hz, =C*H*H), 5.63 (1H, d, *J*=1.2 Hz, =CH*H*), 4.52 (1H, d, *J*=11.2 Hz, OC*H*HPh), 4.49 (1H, d, *J*=11.2 Hz, OCH*H*Ph), 3.73 (3H, s, OCH_3), 3.56 (1H, m, C*H*OBn), 2.60 (1H, dd, *J*=14.0, 6.8 Hz, C*H*HCHOBn), 2.50 (1H, dd, *J*=14.0, 5.6 Hz, CH*H*CHOBn), 1.61–1.20 (12H, m, $(CH_2)_6CH_3$) and 0.88 (3H, d, *J*=6.4 Hz, $(CH_2)_6CH_3$); ^{13}C NMR (100.4 MHz) δ 167.6, 138.7, 137.4, 128.1, 127.7, 127.3, 127.2, 77.6, 71.8, 51.8, 37.3, 34.1, 31.9, 29.7, 29.3, 25.4, 22.7 and 14.2; MS *m*/*z* 318 (M^+, 1.8%), 278 (10), 277 (21), 219 (47), 212 (20), 195 (10), 181 (27), 180 (16), 179 (13), 158 (18), 130 (38), 127 (21), 105 (21) and 91 (100); HRMS calcd for $C_{20}H_{30}O_3$ [M^+] 318.2195, found 318.2182.

4.2.2. γ-Benzyloxy-αmethylene ester 10. ^{1}H NMR (400 MHz) δ 7.32–7.24 (5H, m, Ph), 6.21 (1H, d, *J*=1.6 Hz, =C*H*H), 5.60 (1H, d, *J*=1.6 Hz, =CH*H*), 4.82 (1H, m, CO_2CH), 4.54 (1H, d, *J*=11.6 Hz, OCHHPh), 4.49 (1H, d, *J*=11.6 Hz, OCHHPh), 3.57 (1H, m, CHOBn), 2.61 (1H, dd, *J*=14.0, 6.8 Hz, CHHCHOBn), 2.48 (1H, dd, *J*=14.0, 6.0 Hz, CHHCHOBn), 1.83 (2H, m, CH_2), 1.72 (2H, m, CH_2), 1.53–1.26 (18H, m, $(CH_2)_3$ and $(CH_2)_6CH_3$) and 0.88 (3H, d, *J*=6.8 Hz, $(CH_2)_6CH_3$); ^{13}C NMR (100.4 MHz) δ 166.5, 138.8, 138.1, 128.2, 127.7, 127.3, 126.9, 77.8, 72.8, 71.3, 37.4, 34.2, 31.9, 31.6, 29.7, 29.3, 25.5, 25.4, 23.7, 22.7 and 14.2; MS *m*/*z* 287 (M^+−O*c*-C_6H_{11}, 6%), 239 (11), 220 (12), 219 (72), 205 (13), 198 (50), 176 (36), 158 (16), 130 (90), 127 (31), 116 (26), 107 (28), 92 (69) and 91 (100); HRMS calcd for $C_{19}H_{27}O_2$ [M^+−O*c*-C_6H_{11}] 287.2011, found 287.2005.

4.2.3. γ-Benzyloxy-α-methylene ester 15. ^{1}H NMR (270 MHz) δ 7.36–7.24 (5H, m, Ph), 6.20 (1H, d, *J*=2.0 Hz, =C*H*H), 5.64 (1H, d, *J*=2.0 Hz, =CH*H*), 4.49 (2H, dd, *J*=13.2, 11.5 Hz, $PhCH_2$), 4.18 (2H, q, *J*=7.3 Hz, $CO_2CH_2CH_3$), 3.40 (1H, m, 4-H), 2.57 (1H, dd, *J*=13.9, 4.3 Hz, 3-H), 2.44 (1H, dd, *J*=13.9, 7.6 Hz, 3-H), 1.90 (1H, m, $(CH_3)_2CH$), 1.28 (3H, t, *J*=7.3 Hz, $CO_2CH_2CH_3$), 0.97 (3H, d, *J*=4.3 Hz, CH_3) and 0.95 (3H, d, *J*=4.3 Hz, CH_3); ^{13}C NMR (67.8 MHz) δ 167.15, 138.81, 138.07, 128.08, 127.61, 127.23, 126.94, 82.51, 72.15, 60.62, 34.01, 30.98, 18.23, 17.86 and 14.28; MS *m*/*z* 276 (M^+, 7%), 233 (M^+−C_3H_7, 36), 170 (49), 163 (100), 158 (59), 130 (76), 115 (40) and 91 (100); HRMS calcd for $C_{17}H_{24}O_3$ [M^+] 276.1726, found 276.1755.

4.2.4. γ-Benzyloxy-α-methylene ester 16. ^{1}H NMR (400 MHz) δ 7.46–7.16 (13H, m, Ph), 6.94 (2H, m, Ph), 6.19 (1H, s, =C*H*H), 5.56 (1H, s, =CH*H*), 4.38 (1H, ddd, *J*=8.0, 8.0, 4.1 Hz, CHO), 4.27 (1H, d, *J*=10.4 Hz, OC*H*HPh), 4.19(2H, q, *J*=7.3 Hz $CO_2CH_2CH_3$), 4.04 (1H, d, *J*=8.0 Hz, CH), 3.99 (1H, d, *J*=10.3 Hz, OCH*H*Ph), 2.68 (1H, dd, *J*=13.9, 4.8 Hz, C*H*HC=CH_2), 2.43 (1H, dd, *J*=13.9, 8.1 Hz, CH*H*C=CH_2) and 1.30 (3H, t, *J*=7.3 Hz CO_2CH_2CH3); ^{13}C NMR (100.4 MHz) δ 167.0, 142.3, 141.9, 138.0, 137.4, 129.2 (2C), 128.5 (2C), 128.4 (2C), 128.1 (2C), 128.0 (4C), 127.8, 127.3, 126.3, 126.3, 80.9, 73.3, 60.7, 57.2, 37.3 and 14.3; MS *m*/*z* 355 (M^+−OEt, 1%), 233(49), 167(89) and 91(100); HRMS calcd for $C_{25}H_{23}O_2$ (M^+−C_2H_5O) 355.1698, found 355.1728.

4.2.5. γ-Benzyloxy-α-methylene ester 17. ^{1}H NMR (400 MHz) δ 7.40–7.17 (5H, m, Ph), 6.20 (1H, s, =C*H*H), 5.64 (1H, s, =CH*H*), 4.47 (2H, s, OCH_2Ph), 4.18 (2H, q, *J*=7.3 Hz, $CO_2CH_2CH_3$), 3.38 (1H, ddd, *J*=8.3, 3.4, 3.4 Hz, CHO), 2.61 (1H, dd, *J*=14.2, 3.4 Hz, C*H*HC=CH_2), 2.44 (1H, dd, *J*=14.2, 8.3 Hz, CH*H*C=CH_2), 1.83–1.68 (6H, m), 1.28 (3H, t, *J*=7.3 Hz, $CO_2CH_2CH_3$) and 1.25–1.10 (5H, m); ^{13}C NMR (67.8 MHz) δ 167.1, 138.8, 138.1, 128.1 (2C), 127.6 (2C), 127.2, 126.9, 82.2, 72.3, 60.6, 41.5, 34.4, 29.0, 28.4, 26.7, 26.5 (2C) and 14.3; MS *m*/*z* 316 (M^+, 3%), 233(15), 203(89), 92(79) and 91(100); HRMS calcd for $C_{20}H_{28}O_3$ [M^+] 316.2038, found 316.2044.

4.2.6. 1,3-Dithiane 47. Following the procedures reported by Hazra and co-workers,[9] the alcohol **46** was prepared from isobutyraldehyde and 1,3-dithiane in 95% yield. To a cooled (0°C) solution of the alcohol **46** (463 mg, 2.4 mmol) and imidazole (1.09 g, 16.0 mmol) in dry DMF (10 cm^3) was added *tert*-butylchlorodimethylsillane (759 mg, 5.04 mmol), and the solution was stirred at room temperature overnight. After addition of chilled water, the product was extracted with hexane. The organic layer was washed with water and saturated brine, and then dried over anhydrous sodium sulfate. The solvent was evaporated in vacuo and the residue was chromatographed on silica gel (eluent: hexane–ethyl acetate (30:1, v/v)) to give the silyl ether **47** (350 mg, 47% yield). ^{1}H NMR (400 MHz) δ 4.22 (1H, d, J=4.6 Hz, SCHS), 3.56 (1H, t, J=4.6 Hz, CHO), 2.85 (4H, m, 2×CH_2S), 2.08 (1H, m, C*H*H), 2.01 (1H, m, CH*H*), 1.86 (1H, m, C*H*(CH_3)$_2$), 0.97 (3H, d, J=6.8 Hz, CHC*H*$_3$), 0.94 (3H, d, J=6.8 Hz, CHC*H*$_3$), 0.94 (9H, s, C(CH_3)$_3$), 0.19 (3H, s, SiCH_3) and 0.08 (3H, s, SiCH_3); ^{13}C NMR (100.4 MHz) δ 79.3, 54.5, 32.5, 31.4, 30.9, 26.6, 26.2, 20.3, 18.6, 17.5, −3.6 and −3.9.

4.2.7. 1,3-Dithiane 49. Following the procedures reported by Hazra and co-workers,[9] the alcohol **48** was prepared from benzaldehyde and 1,3-dithiane in 96% yield. To a cooled (0°C) solution of the alcohol **48** (163 mg, 0.72 mmol) and imidazole (307 mg, 4.51 mmol) in dry DMF (3 cm^3) was added *tert*-butylchlorodimethylsillane (220 mg, 1.46 mmol), and the solution was stirred at room temperature overnight. After addition of chilled water, the product was extracted with hexane. The organic layer was washed with water and saturated brine, and then dried over anhydrous sodium sulfate. The solvent was evaporated in vacuo and the residue was chromatographed on silica gel (eluent: hexane–ethyl acetate (30:1, v/v)) to give the silyl ether **49** (242 mg, 99% yield). ^{1}H NMR (270 MHz) δ 7.37–7.24 (5H, m, Ph), 4.72 (1H, d, J=7.2 Hz, CH–O), 4.26 (1H, d, J=7.2 Hz, CHS_2), 2.84–2.72 (4H, m, SCH_2), 2.04 (1H, m, C*H*H), 1.83 (1H, m, CH*H*), 0.88 (9H, s, C(CH_3)$_3$), 0.08 (3H, s, SiCH_3) and −0.15 (3H, s, SiCH_3); ^{13}C NMR (67.8 MHz) δ 141.5, 128.0, 127.9, 126.8, 77.9, 55.3, 30.2, 29.9, 25.95, 25.86, 18.4, −4.5 and −4.8.

4.2.8. 1,3-Dithiane 50. To a suspension of sodium hydride (60% dispersion in mineral oil; 112 mg, 2.8 mmol) in dry THF (3.0 cm^3) cooled to 0°C were added benzyl bromide (0.38 cm^3, 3.2 mmol) and the alcohol **48** (343 mg, 1.50 mmol). The mixture was stirred at 0°C for 0.5 h and then at room temperature for 2 h. Water was added and the mixture was filtered. After evaporation in vacuo, the residue was chromatographed on silica gel (eluent: hexane–ethyl acetate (10:1, v/v)) to give the benzyl ether **50** (345 mg, 73% yield). ^{1}H NMR (400 MHz) δ 7.40–7.25 (10H, m, 2×Ph), 4.57 (1H, d, J=12.0 Hz, C*H*HPh), 4.49 (1H, d, J=7.2 Hz, C*H*OBn), 4.36 (1H, d, J=7.2 Hz, SCHS), 4.28 (1H, d, J=12.0 Hz, CH*H*Ph), 2.88–2.71 (4H, m, 2×SCH_2), 2.06 (1H, m, C*H*H) and 1.85 (1H, m, CH*H*); ^{13}C NMR (100.4 MHz) δ 138.0, 137.4, 128.6, 128.3, 128.0, 127.7, 127.6, 82.6, 70.9, 53.1, 30.3, 30.0 and 25.9.

4.2.9. 1,3-Dithiane 51. To a suspension of sodium hydride (60% dispersion in mineral oil; 192 mg, 4.8 mmol) in dry THF (25 cm^3) cooled to 0°C were added the alcohol **48** (577 mg, 2.55 mmol) and iodomethane (0.8 cm^3, 12.8 mmol). The mixture was stirred at 0°C for 0.5 h and then at room temperature for 0.5 h. Water was added and the mixture was filtered. After evaporation, the crude product was chromatographed on silica gel (eluent: hexane–ethyl acetate (20:1, v/v)) to give the methyl ether **51** (426 mg, 70% yield). ^{1}H NMR (400 MHz) δ 7.41–7.35 (5H, m, Ph), 4.34 (1H, s, CH), 3.29 (3H, s, OCH_3), 2.89–2.77 (4H, m, 2×SCH_2), 2.06 (1H, m, C*H*H) and 1.88 (1H, m, CH*H*); ^{13}C NMR (100.4 MHz) δ 137.9, 128.5, 128.2, 127.3, 85.7, 57.5, 53.4, 30.5, 30.2 and 25.9.

4.2.10. Aldehyde 52. To a solution of the dithiane **47** (123 mg, 0.40 mmol) in acetone (8.0 cm^3) was added $BaCO_3$ (1.11 g, 5.6 mmol) at 0°C. A solution of *N*-bromosuccinimide (170 mg, 0.96 mmol) in acetone (10 cm^3) was added and the mixture was stirred at room temperature for 1 h. An excess of *N*-bromosuccinimide was decomposed with 10% aqueous sodium disulfite. After filtration and concentration, sodium chloride was added. The product was then extracted with ether. The organic layer was washed with water and saturated brine, and then dried over anhydrous sodium sulfate. After evaporation in vacuo, the residue was chromatographed on silica gel (eluent: hexane–ethyl acetate (30:1, v/v)) to give the aldehyde **52** (67 mg, 77% yield). ^{1}H NMR (400 MHz) δ 9.59 (1H, d, J=2.2 Hz, CH═O), 3.72 (1H, dd, J=4.9, 2.2 Hz, CHO), 2.03 (1H, m, C*H*(CH_3)$_2$), 0.97 (3H, d, J=7.1 Hz, CHC*H*$_3$), 0.93 (9H, s, C(CH_3)$_3$), 0.92 (3H, d, J=6.4 Hz, CHC*H*$_3$) and 0.06 (3H, s, 2×SiCH_3); ^{13}C NMR (100.4 MHz) δ 204.8, 82.0, 31.5, 25.8, 18.8, 18.3, 16.9, −4.5 and −5.0.

4.2.11. Aldehyde 53. To a solution of the dithiane **49** (242 mg, 0.71 mmol) in acetone (13 cm^3) was added $BaCO_3$ (1.78 g, 9.0 mmol) at 0°C. A solution of *N*-bromosuccinimide (289 mg, 1.62 mmol) in acetone (20 cm^3) was added and the mixture was stirred at room temperature for 1 h. Work-up as described above gave the aldehyde **53** (158 mg, 89% yield). ^{1}H NMR (270 MHz) δ 9.51 (1H, d, J=2.2 Hz, CH═O), 7.40–7.25 (5H, m, Ph), 5.00 (1H, d, J=2.2 Hz, CH–O), 0.95 (9H, s, C(CH_3)$_3$), 0.12 (3H, s, SiCH_3) and 0.05 (3H, s, SiCH_3); ^{13}C NMR (67.8 MHz) δ 199.3, 136.5, 128.6, 128.3, 126.3, 80.0, 25.8, 18.4 and −4.7.

4.2.12. Aldehyde 54. Treatment of the dithiane **50** (345 mg, 1.09 mmol) with $BaCO_3$ (2.71 g, 13.8 mmol) and *N*-bromosuccinimide (377 mg, 2.10 mmol) in acetone (65 cm^3) as described above gave the aldehyde **54** (174 mg, 71% yield). ^{1}H NMR (400 MHz) δ 9.62 (1H, d, J=1.8 Hz, CH═O), 7.43–7.24 (10H, m, 2×Ph), 4.80 (1H, d, J=1.8 Hz, CH), 4.66 (1H, d, J=11.7 Hz, C*H*HPh) and 4.54 (1H, d, J=11.7 Hz, CH*H*Ph); ^{13}C NMR (100.4 MHz) δ 198.2, 136.9, 133.8, 128.95, 128.85, 128.5, 128.0, 127.9, 127.5, 85.4 and 71.1.

4.2.13. Aldehyde 55. Treatment of the dithiane **51** (408 mg, 1.70 mmol) with $BaCO_3$ (4.52 g, 22.9 mmol) and *N*-bromosuccinimide (727 mg, 4.08 mmol) in acetone (23 cm^3) as described above gave the aldehyde **55** (256 mg, 100% yield). ^{1}H NMR (400 MHz) δ 9.60 (1H, d, J=1.7 Hz, CH═O), 7.44–7.36 (5H, m, Ph), 4.65 (1H, d, J=1.7 Hz, CH) and 3.45 (3H, s, OCH_3); ^{13}C NMR (100.4 MHz) δ 198.1, 133.6, 129.0, 128.9, 127.4, 88.2 and 57.3.

4.2.14. Compounds 56 and 57. To a solution of the aldehyde **52** (423 mg, 1.7 mmol) in THF (2.0 cm^3) were added ethyl 2-(bromomethyl)propenoate (656 mg, 3.4 mmol) and saturated aqueous ammonium chloride (10 cm^3). Zinc powder (302 mg, 4.6 mmol) was added at 0°C, and the reaction mixture was stirred at this temperature for 2 h. The product was extracted with ethyl acetate. The organic layer was washed with water and saturated brine, and then dried over anhydrous sodium sulfate. The solvent was evaporated in vacuo and the residue was chromatographed on silica gel (eluent: hexane–ethyl acetate (30:1, v/v)) to give the hydroxy esters **56** and **57** (522 mg, 81% yield) in a ratio of 3.3:1.

More polar, major diastereomer **56**. ^{1}H NMR (400 MHz) δ 6.25 (1H, d, J=1.5 Hz, =C*H*H), 5.66 (1H, s, =CH*H*), 4.22, (2H, m, C*H*$_2$CH$_3$), 3.78 (1H, m, C*H*OH), 3.45 (1H, dd, J=5.6, 3.7 Hz, CH–O), 2.61 (1H, br d, J=14.2 Hz, C*H*H(C=CH$_2$), 2.35 (1H, dd, J=14.2, 10.2 Hz, CH*H*C=CH$_2$), 2.23 (1H, d, J=4.9 Hz, OH), 1.81 (1H, m, C*H*(CH$_3$)$_2$), 1.30 (3H, t, J=7.2 Hz, CH$_2$C*H*$_3$), 0.96 (3H, d, J=6.8 Hz, CH$_3$), 0.93 (3H, d, J=6.8 Hz, CH$_3$), 0.93 (9H, s, C(CH$_3$)$_3$), 0.11 (3H, s, SiCH$_3$) and 0.09 (3H, s, SiCH$_3$); ^{13}C NMR (100.4 MHz) δ 167.5, 138.1, 127.2, 80.3, 72.4, 60.9, 34.8, 30.7, 26.1, 20.0, 18.8, 18.5, 14.2, −3.7 and −4.2; HRMS calcd for $C_{13}H_{25}O_4Si$ [$M^+-C_4H_9$] 273.1523, found 273.1504.

Less polar, minor diastereomer **57**. ^{1}H NMR (400 MHz) δ 6.16 (1H, d, J=1.7 Hz, =C*H*H), 5.53 (1H, s, =CH*H*), 4.21, (2H, m, C*H*$_2$CH$_3$), 3.78 (1H, m, C*H*OH), 3.38 (1H, dd, J=4.2, 3.2 Hz, CH–O), 2.47 (1H, d, J=7.3 Hz, OH), 2.44 (1H, dd, J=14.2, 3.1 Hz, C*H*HC=CH$_2$), 2.36 (1H, dd, J=14.2, 9.0 Hz, CH*H*C=CH$_2$), 1.84 (1H, m, C*H*(CH$_3$)$_2$), 1.29 (3H, t, J=7.2 Hz, CH$_2$CH$_3$), 0.96 (3H, d, J=6.8 Hz, CH$_3$), 0.94 (9H, s, C(CH$_3$)$_3$), 0.90(3H, d, J=6.8 Hz, CH$_3$), 0.12 (3H, s, SiCH$_3$) and 0.11 (3H, s, SiCH$_3$); ^{13}C NMR (100.4 MHz) δ 166.9, 139.7, 125.1,78.9, 69.5, 60.7, 32.2, 30.9, 26.1, 18.7, 18.4, 18.0, 14.3, −3.8 and −4.1; HRMS calcd for $C_{13}H_{25}O_4Si$ [$M^+-C_4H_9$] 273.1523, found 273.1528.

4.2.15. Compounds 58 and 59. To a solution of the aldehyde **53** (252 mg, 1.0 mmol) in THF (1.0 cm^3) were added ethyl 2-(bromomethyl)propenoate (320 mg, 1.7 mmol) and saturated aqueous ammonium chloride (5.0 cm^3). Zinc powder (132 mg, 2.0 mmol) was added at 0°C, and the reaction mixture was stirred at this temperature for 2 h. The product was extracted with ethyl acetate. The organic layer was washed with water and saturated brine, and then dried over anhydrous sodium sulfate. The solvent was evaporated in vacuo and the residue was chromatographed on silica gel (eluent: hexane–ethyl acetate (30:1, v/v)) to give the hydroxy esters **58** and **59** (263 mg, 89% yield) in a ratio of 1.7:1.

More polar, major diastereomer **58**. ^{1}H NMR (270 MHz) δ 7.34–7.23 (5H, m, Ph), 6.19 (1H, d, J=1.7 Hz, =C*H*H), 5.58 (1H, d, J=1.3 Hz, CH*H*), 4.66 (1H, d, J=5.6 Hz, CH–O), 4.17 (2H, m, C*H*$_2$CH$_3$), 3.83 (1H, m, C*H*OH), 2.60 (1H, dd, J=14.5, 1.7 Hz, C*H*H), 2.35 (1H, d, J=4.2 Hz, OH), 2.26 (1H, dd, J=14.5, 10.2 Hz, CH*H*), 1.26 (3H, t, J=7.0 Hz, CH$_3$), 0.92 (9H, s, C(CH$_3$)$_3$), 0.08 (3H, s, SiCH$_3$) and −0.14 (3H, s, SiCH$_3$); ^{13}C NMR (67.8 MHz) δ 167.5, 141.1, 137.9, 128.0, 127.4, 127.0, 126.8, 78.0, 75.3, 60.8, 34.5, 25.9, 18.3, 14.2, −4.5 and −4.9; HRMS calcd for $C_{16}H_{23}O_4Si$ [$M^+-C_4H_9$] 307.1366, found 307.1358.

Less polar, minor diastereomer **59**. ^{1}H NMR (270 MHz) δ 7.39–7.26 (5H, m, Ph), 6.19 (1H, d, J=1.7 Hz, =C*H*H), 5.63 (1H, d, J=1.3 Hz, CH*H*), 4.47 (1H, d, J=5.9 Hz, CH–O), 4.14 (2H, q, J=7.0 Hz, C*H*$_2$CH$_3$), 3.83 (1H, m, C*H*OH), 2.77 (1H, d, J=3.6 Hz, OH), 2.38 (1H, dd, J=13.7, 2.5 Hz, C*H*H), 2.24 (1H, dd, J=13.7, 9.6 Hz, CH*H*), 1.23 (3H, t, J=7.0 Hz, CH$_3$), 0.89 (9H, s, C(CH$_3$)$_3$), 0.05 (3H, s, SiCH$_3$) and −0.20 (3H, s, SiCH$_3$); ^{13}C NMR (67.8 MHz) δ 167.1, 141.0, 137.5, 128.0, 127.7, 127.1, 126.6, 78.8, 74.9, 60.7, 35.4, 25.9, 18.2, 14.2, −4.4 and −5.0; HRMS calcd for $C_{16}H_{23}O_4Si$ [$M^+-C_4H_9$] 307.1366, found 307.1407.

4.2.16. γ-Benzyloxy-α-methylene ester 18. To a solution of the alcohol **56** (139 mg, 0.46 mmol) in cyclohexane–dichloromethane (2:1, v/v; 5 cm^3) were added successively benzyl 2,2,2-trichloroacetimidate (0.17 cm^3) and trifluoromethanesulfonic acid (0.03 cm^3). The reaction mixture was stirred at room temperature for 0.5 h. After dilution with diethyl ether, the solution was washed successively with saturated aqueous sodium hydrogencarbonate, water and brine, and dried over anhydrous sodium sulfate. The solvent was evaporated in vacuo and the residue was chromatographed on silica gel (eluent: hexane–ethyl acetate (30:1, v/v) and then hexane–benzene (1:1)) to give **18** (155 mg; 87% yield). ^{1}H NMR (400 MHz) δ 7.37–7.24 (5H, m, Ph), 6.16 (1H, d, J=1.5 Hz, =C*H*H), 5.62 (1H, s, CH*H*), 4.57 (1H, d, J=11.8 Hz, C*H*HPh), 4.44 (1H, d, J=11.8 Hz, CH*H*Ph), 4.15, (2H, m, CH$_2$CH$_3$), 3.57 (1H, m, C*H*OBn), 3.51 (1H, t, J=5.2 Hz, C*H*–OTBDMS), 2.67 (1H, dd, J=14.4 and 2.2 Hz, C*H*H), 2.46 (1H, dd, J=14.4, 9.6 Hz, CH*H*), 1.88 (1H, m, C*H*(CH$_3$)$_2$), 1.25 (3H, t, J=7.2 Hz, CH$_2$CH$_3$), 0.97 (3H, d, J=6.8 Hz, CH$_3$), 0.93 (3H, d, J=6.6 Hz, CH$_3$), 0.91 (9H, s, C(CH$_3$)$_3$), 0.04 (3H, s, SiCH$_3$) and 0.01 (3H, s, SiCH$_3$); ^{13}C NMR (100.4 MHz) δ 167.2, 138.8, 138.3, 128.0, 127.5, 127.2, 126.6, 81.0, 72.4, 60.6, 33.0, 30.1, 26.1, 20.7, 18.7, 18.3, 14.3, −3.8 and −4.3; HRMS m/z calcd for $C_{20}H_{31}O_4Si$ [$M^+-C_4H_9$] 363.1991, found 363.1991.

4.2.17. γ-Benzyloxy-α-methylene ester 19. The benzylation of alcohol **58** performed as described above gave the benzyl ether **19** (216 mg, 58% yield). ^{1}H NMR (400 MHz) δ 7.38–7.08 (10H, m, 2×Ph), 6.18 (1H, d, J=1.8 Hz, =C*H*H), 5.60 (1H, s, CH*H*), 4.67 (1H, d, J=5.4 Hz, PhC*H*–O), 4.21 (1H, d, J=11.0 Hz, C*H*HPh), 4.13 (1H, d, J=11.0 Hz, CH*H*Ph), 4.09 (2H, m, C*H*HCH$_3$), 3.67 (1H, m, C*H*–OBn), 2.78 (1H, dd, J=14.0, 1.1 Hz, C*H*H), 2.36 (1H, dd, J=14.0, 9.8 Hz, CH*H*), 1.20 (3H, t, J=7.1 Hz, CH$_3$), 0.91 (9H, s, C(CH$_3$)$_3$), 0.06 (3H, s, SiCH$_3$) and −0.17 (3H, s, SiCH$_3$); ^{13}C NMR (67.8 MHz) δ 167.0, 142.3, 138.1, 137.8, 128.1, 128.0, 127.8, 127.3, 127.2, 127.1, 82.9, 76.9, 73.3, 60.5, 34.4, 25.9, 18.3, 14.2, −4.5 and −4.8; MS m/z 397 ($M^+-C_4H_9$, 2%), 221 (74) and 91 (100); HRMS calcd for $C_{23}H_{29}O_4Si$ [$M^+-C_4H_9$] 397.1835, found 397.1838.

4.2.18. γ-Benzyloxy-α-methylene esters 20 and 24. Treatment of the aldehyde **54** (174 mg, 0.77 mmol) with ethyl 2-(bromomethyl)propenoate (240 mg, 1.24 mmol) and

zinc powder (122 mg, 1.9 mmol) in THF (0.8 cm^3)-saturated aqueous ammonium chloride (4.0 cm^3) as described above gave an inseparable mixture of the hydroxy esters **60** and **61** (220 mg, 84% yield), in a ratio of 1.7:1. Treatment of the alcohols (137 mg, 0.40 mmol) with benzyl 2,2,2-trichloroacetimidate (0.16 cm^3) and trifluoromethanesulfonic acid (0.025 cm^3) as described above gave an inseparable mixture of **20** and **24** (139 mg, 80% yield) in a ratio of 1.7:1.

Compound **20**. ^{1}H NMR (400 MHz) δ 7.42–7.02 (15H, m, 3×Ph), 6.18 (1H, d, J=1.5 Hz, =C*H*H), 5.60 (1H, s, =CH*H*), 4.71–4.06 (7H, m, 2×PhCH_2, C*H*OBn and OCH_2CH$_3$), 3.82 (1H, m, C*H*OBn), 2.87 (1H, dd, J=14.0, 3.2 Hz, C*H*HC=CH$_2$), 2.47 (1H, dd, J=14.0, 8.8 Hz, CH*H*C=CH$_2$) and 1.22 (3H, t, J=7.2 Hz, CH$_3$).

Compound **24**. ^{1}H NMR (400 MHz) δ 7.42–7.02 (15H, m, 3×Ph), 6.11 (1H, d, J=1.5 Hz, =C*H*H), 5.44 (1H, s, =CH*H*), 4.71–4.06 (7H, m, 2×PhCH_2, C*H*OBn and OCH_2CH$_3$), 3.82 (1H, m, C*H*OBn), 2.39 (2H, m, CH_2-C=CH$_2$) and 1.22 (3H, t, J=7.2 Hz, CH$_3$). **20** and **24**. MS *m*/*z* 323 ($M^+-OC_7H_7$, 3%), 233 (99) and 91 (100); HRMS calcd for $C_{21}H_{23}O_3$ [$M^+-OC_7H_7$] 323.1647, found 323.1674.

4.2.19. γ-Benzyloxy-α-methylene esters 21 and 25. Treatment of the aldehyde **55** (256 mg, 1.7 mmol) with ethyl 2-(bromomethyl)propenoate (520 mg, 2.7 mmol) and zinc powder (292 mg, 4.5 mmol) in THF (1.7 cm^3)-saturated aqueous ammonium chloride (8.5 cm^3) as described above gave an inseparable mixture of the hydroxy esters **62** and **63** (277 mg, 61% yield) in a ratio of 1.3:1.

Compound **62**. ^{1}H NMR (400 MHz) δ 7.40–7.26 (5H, m, 2, Ph), 6.20 (1H, s, =C*H*H), 5.64 (1H, m, CH*H*), 4.24–3.94 (4H, m, C*H*OH, C*H*OCH$_3$ and CH_2CH$_3$), 3.25 (3H, s, OCH$_3$) and 1.24 (3H, t, J=7.1 Hz, OCH$_2$CH_3).

Compound **63**. ^{1}H NMR (400 MHz) δ 7.40–7.26 (5H, m, 2, Ph), 6.22 (1H, s, =C*H*H), 5.63 (1H, m, CH*H*), 4.24–3.94 (4H, m, C*H*OH, C*H*OCH$_3$ and CH_2CH$_3$), 3.29 (3H, s, OCH$_3$) and 1.26 (3H, t, J=7.1 Hz, OCH$_2$CH_3). The benzylation of the mixture with benzyl 2,2,2-trichloroacetimidate (0.33 cm^3) and trifluoromethanesulfonic acid (0.05 cm^3) as described above gave an inseparable mixture of **21** and **25** in 25% yield (not optimized) and in a ratio of 1:1.3.

Compound **21**. ^{1}H NMR (400 MHz) δ 7.38–7.05 (10H, m, 2×Ph), 6.19 (1H, s, =C*H*H), 5.62 (1H, s, CH*H*), 4.32 (1H, d, J=11.2 Hz, C*H*HPh), 4.21–4.08 (4H, m, CH*H*Ph, C*H*OCH$_3$ and CH_2CH$_3$), 3.73 (1H, m, C*H*OBn), 3.25 (3H, s, OCH$_3$), 2.78 (1H, dd, J=14.2, 3.4 Hz, C*H*HC=CH$_2$), 2.46 (1H, m, C*H*HC=CH$_2$) and 1.20 (3H, t, J=7.2 Hz, CH$_3$).

Compound **25**. ^{1}H NMR (400 MHz) δ 7.38–7.05 (10H, m, 2×Ph), 6.19 (1H, s, =C*H*H), 5.61 (1H, s, CH*H*), 4.46 (1H, d, J=11.5 Hz, C*H*HPh), 4.38 (1H, d, J=11.5 Hz, CH*H*Ph), 4.21–4.08 (3H, m, C*H*OCH$_3$ and CH_2CH$_3$), 3.80 (1H, m, C*H*OBn), 3.29 (3H, s, OCH$_3$), 2.46 (m, CH$_2$) and 1.24 (3H, t, J=7.2 Hz, CH$_3$). Compounds **21** and **25**. MS *m*/*z* 323 (M^+-OCH_3, 1%), 91 (100) and 84 (52); HRMS calcd for $C_{21}H_{23}O_3$ [M^+-OC_3] 323.1647, found 323.1604.

4.2.20. γ-Benzyloxy-α-methylene ester 22. The benzylation of alcohol **57** performed as described above gave the benzyl ether **22** in 62% yield. ^{1}H NMR (400 MHz) δ 7.37–7.24 (5H, m, Ph), 6.20 (1H, d, J=1.7 Hz, =C*H*H), 5.63 (1H, s, CH*H*), 4.56 (1H, d, J=11.6 Hz, C*H*HPh), 4.32 (1H, d, J=11.6 Hz, CH*H*Ph), 4.12, (2H, m, CH_2CH$_3$), 3.62 (1H, m, C*H*OBn), 3.53 (1H, dd, J=7.2, 2.0 Hz, C*H*–OTBDMS), 2.52 (2H, m, CH$_2$), 1.75 (1H, m, C*H*(CH$_3$)$_2$), 1.24 (3H, t, J=7.3 Hz, CH$_2$CH$_3$), 0.97 (3H, d, J=6.6 Hz, CH$_3$), 0.91(3H, d, J=6.3 Hz, CH$_3$), 0.91 (9H, s, C(CH$_3$)$_3$), 0.08 (3H, s, SiCH$_3$) and 0.04 (3H, s, SiCH$_3$); ^{13}C NMR (100.4 MHz) δ 167.2, 138.6, 138.0, 128.0, 127.8, 127.5, 127.2, 79.3, 78.8, 71.9, 60.5, 33.2, 31.4, 26.2, 20.0, 19.6, 18.6, 14.3, −3.6 and −4.6; HRMS *m*/*z* calcd for $C_{20}H_{31}O_4Si$ [$M^+-C_4H_9$] 363.1991, found 363.2018.

4.2.21. γ-Benzyloxy-α-methylene ester 23. Treatment of the alcohol **59** (268 mg, 0.79 mmol) with benzyl 2,2,2-trichloroacetimidate (0.3 cm^3) and trifluoromethanesulfonic acid (0.05 cm^3) as described above gave the benzyl ether **23** in 58% yield. ^{1}H NMR (400 MHz) δ 7.36–7.23 (10H, m, 2×Ph), 6.10 (1H, d, J=1.7 Hz, =C*H*H), 5.50 (1H, s, =CH*H*), 4.75 (1H, d, J=5.6 Hz, PhC*H*–O), 4.66 (1H, d, J=11.5 Hz, C*H*HPh), 4.46 (1H, d, J=11.5 Hz, CH*H*Ph), 4.08 (2H, q, J=7.1 Hz, CH_2CH$_3$), 3.77 (1H, ddd, J=10.0, 5.6, 2.9 Hz, C*H*–OBn), 2.42 (1H, dd, J=13.9, 2.9 Hz, C*H*H), 2.08 (1H, dd, J=13.9, 10.0 Hz, CH*H*), 1.21 (3H, t, J=7.6 Hz, CH$_3$), 0.88 (9H, s, C(CH$_3$)$_3$), 0.02 (3H, s, SiCH$_3$) and −0.15 (3H, s, SiCH$_3$); ^{13}C NMR (67.8 MHz) δ 166.9, 141.5, 138.5, 137.5, 128.1, 127.9, 127.7, 127.3, 127.2, 127.1, 81.9, 77.1, 73.6, 60.5, 34.2, 25.9, 18.3, 14.3, −4.6 and −4.8; MS *m*/*z* 397 ($M^+-C_4H_9$, 7%) and 91 (100); HRMS calcd for $C_{23}H_{29}O_4Si$ [$M^+-C_4H_9$] 397.1835, found 397.1849.

4.3. Radical reactions

General procedure of the radical reactions performed in the presence of $MgBr_2$·OEt_2. To a solution of α-methylene ester (0.06 mmol) in 1.5 cm^3 of dry CH_2Cl_2 was added $MgBr_2$·OEt_2 (0.18 mmol, 3 equiv.), and the mixture was stirred at room temperature for 10 min. To the suspension cooled to 0°C were added alkyl iodide R^3I (0.18 mmol, 3 equiv.), *n*-Bu_3SnH (0.12 mmol, 2 equiv.) and Et_3B (1.06 mol dm^{-3} in hexane; 0.06 mmol, 1 equiv.). The mixture was stirred at 0°C for 1 h. KF and water were added and the mixture was stirred at room temperature for 3 h. After filtration, the solvent was evaporated in vacuo. The residue was purified by flash chromatography on silica gel [eluent: hexane–ethyl acetate (20:1 or 10:1)] to give the inseparable diastereomeric adducts.

General procedure of the radical reactions performed in the absence of $MgBr_2$·OEt_2. The radical reaction was performed as described above except for the absence of Lewis acid.

4.3.1. Compound 11 (2,4-*syn*). ^{1}H NMR (400 MHz) δ 7.36–7.24 (5H, m, Ph), 4.49 (1H, d, J=11.2 Hz, OC*H*HPh), 4.42 (1H, d, J=11.2 Hz, OCH*H*Ph), 3.56 (3H, s, CO_2CH_3), 3.31 (1H, m, C*H*OBn), 2.76 (1H, m, C*H*CO_2CH_3), 1.87 (1H,

m, C*H*HCHOBn), 1.63–1.16 (16H, m, CH*H*CHOBn, $(CH_2)_6CH_3$, $CH_2CH(CH_3)_2$ and $CH(CH_3)_2$), 0.90 (3H, d, J=6.4 Hz, $CH(CH_3)_2$), 0.88 (3H, t, J=6.4 Hz, CH_3) and 0.87 (3H, d, J=6.4 Hz, $CH(CH_3)_2$); ^{13}C NMR (100.4 MHz) δ 177.1, 138.7, 128.2, 127.9, 127.4, 71.3, 51.3, 42.6, 39.9, 37.6, 34.0, 31.8, 29.9, 29.3, 26.2, 25.2, 23.0, 22.7, 22.3 and 14.2; MS m/z 362 (M^+, 1.5%), 263 (9), 239 (28), 236 (17), 130 (59), 92 (11) and 91 (100); HRMS calcd for $C_{23}H_{38}O_3$ (M^+) 362.2821, found 362.2834.

4.3.2. Compound 12 (2,4-*syn* and 24-*anti*). MS m/z 277 ($M^+-C_7H_{15}$, 4%), 253 (11), 149 (7), 144 (36), and 91 (100); HRMS calcd for $C_{17}H_{25}O_3$ ($M^+-C_7H_{15}$) 277.1804, found 277.1810.

Compound syn-**12**. ^{1}H NMR (400 MHz) δ 7.38–7.26 (5H, m, Ph), 4.50 (1H, d, J=11.2 Hz, OC*H*HPh), 4.43 (1H, d, J=11.2 Hz, OCH*H*Ph), 3.59 (3H, s, CO_2CH_3), 3.27 (1H, m, C*H*OBn), 2.75 (1H, m, $CHCO_2CH_3$), 1.76 (1H, m, CH_2-CHOBn), 1.62–1.16 (14H, m, CH_2t-Bu and $(CH_2)_6CH_3$), 0.92 (3H, d, J=7.2 Hz, $(CH_2)_6CH_3$) and 0.87 (9H, s, $C(CH_3)_3$); ^{13}C NMR (100.4 MHz) δ 177.9, 138.7, 128.2, 127.9, 127.4, 77.4, 71.4, 51.4, 47.3, 40.0, 38.3, 34.0, 31.9, 30.9, 29.8, 29.4, 29.3, 25.2, 22.7 and 14.2.

Compound anti-**12**. ^{1}H NMR (400 MHz) δ 7.38–7.26 (5H, m, Ph), 4.51 (1H, d, J=11.2 Hz, OC*H*HPh), 4.42 (1H CH_2i-Pr, d, J=11.2 Hz, OCH*H*Ph), 3.54 (3H, s, CO_2CH_3), 3.33 (1H, m, C*H*OBn), 2.55 (1H, m, $CHCO_2CH_3$), 1.93 (1H, m, CH_2CHOBn), 1.62–1.16 (14H, m, CH_2t-Bu and $(CH_2)_6CH_3$), 0.89 (3H, d, J=7.2 Hz, $(CH_2)_6CH_3$) and 0.86 (9H, s, $C(CH_3)_3$); ^{13}C NMR (100.4 MHz) δ 177.9, 138.7, 128.1, 127.7, 127.3, 77.2, 70.5, 51.4, 46.7, 39.5, 39.1, 33.7, 31.8, 30.8, 29.8, 29.4, 29.2, 25.0, 22.7 and 13.7.

4.3.3. Compound 13 (2,4-*syn*). ^{1}H NMR (400 MHz) δ 7.38–7.26 (5H, m, Ph), 4.77 (1H, m, CO_2CH), 4.51 (1H, d, J=11.2 Hz, OC*H*HPh), 4.45 (1H, d, J=11.2 Hz, OCH*H*Ph), 3.33 (1H, m, C*H*OBn), 2.76 (1H, m, $CHCO_2$), 1.86–1.15 (27H, m, CH_2CHOBn, $(CH_2)_5$, $CH_2CH(CH_3)_2$ and $(CH_2)_6CH_3$), 0.91 (3H, d, J=6.8 Hz, $CH(CH_3)_2$), 0.88 (3H, d, J=6.8 Hz, CH_3) and 0.87 (3H, d, J=6.8 Hz, $CH(CH_3)_2$); ^{13}C NMR (100.4 MHz) δ 176.0, 138.9, 128.2, 127.8, 127.3, 77.9, 72.1, 71.6, 42.8, 40.4, 38.2, 34.3, 31.9, 31.8, 31.7, 29.8, 29.3, 26.2, 25.5, 25.2, 23.8, 23.2, 22.7, 22.1 and 14.2; MS m/z 331 ($M^+-C_7H_{15}$, 19%), 250 (12), 249 (64), 220 (20), 205 (70), 198 (58), 116 (56) and 91 (100); HRMS calcd for $C_{21}H_{31}O_3$ ($M^+-C_7H_{15}$) 331.2273, found 331.2287.

4.3.4. Compound 14 (2,4-*syn* and 24-*anti*). MS m/z 353 (M^+-Bn, 3%), 345 (10), 263 (24), 255 (17), 253 (53), 213 (14), 212 (96), 155 (28), 130 (94), 127 (12), 92 (24) and 91 (100); HRMS calcd for $C_{22}H_{41}O_3$ (M^+-Bn) 353.3056, found 353.3075.

Compound syn-**14**. ^{1}H NMR (400 MHz) δ 7.40–7.26 (5H, m, Ph), 4.74 (1H, m, CO_2CH), 4.51 (1H, d, J=11.2 Hz, OC*H*HPh), 4.50 (1H, d, J=11.2 Hz, OCH*H*Ph), 3.31 (1H, m, C*H*OBn), 2.72 (1H, m, $CHCO_2$), 1.85–1.15 (26H, m, $(CH_2)_5$, CH_2CHOBn, CH_2t-Bu and $(CH_2)_6CH_3$), 0.90 (3H, t, J=7.2 Hz, CH_3) and 0.88 (9H, s, $C(CH_3)_3$); ^{13}C NMR (100.4 MHz) δ 176.8, 138.9, 128.2, 127.8, 127.3, 77.7, 72.2, 71.6, 47.4, 40.6, 38.9, 34.2, 31.9, 31.8, 31.6, 31.0, 29.8, 29.6, 29.2, 25.5, 25.2, 23.9, 23.8 and 22.7.

Compound anti-**14**. ^{1}H NMR (400 MHz) δ 7.40–7.26 (5H, m, Ph), 4.72 (1H, m, CO_2CH), 4.51 (1H, d, J=11.2 Hz, OC*H*HPh), 4.47 (1H, d, J=11.2 Hz, OCH*H*Ph), 3.33 (1H, m, C*H*OBn), 2.48 (1H, m, $CHCO_2$), 1.85–1.15 (26H, m, $(CH_2)_5$, CH_2CHOBn, CH_2t-Bu and $(CH_2)_6CH_3$), 0.92 (3H, t, J=7.2 Hz, CH_3) and 0.87(9H, s, $C(CH_3)_3$); ^{13}C NMR (100.4 MHz) δ 176.8, 138.9, 128.1, 127.7, 127.3, 77.7, 72.2, 70.4, 46.7, 40.6, 39.1, 34.2, 31.9, 31.8, 31.6, 30.9, 29.8, 29.6, 29.3, 25.4, 25.2, 23.9, 23.8 and 22.7.

4.3.5. Compound 26 (2,4-*syn* and 2,4-*anti*). MS m/z 277 (M^+-i-Pr, 43%), 275 (5.5), 250 (11), 185 (25), 183 (12), 144 (82), 101 (52) and 91 (100); HRMS calcd for $C_{17}H_{25}O_3$ [M^+-i-Pr] 277.1804, found 277.1767.

Compound 2,4-*syn*-**26**. ^{1}H NMR (270 MHz) δ 7.28 (5H, m, Ph), 4.53 (1H, d, J=11.2 Hz, C*H*HPh), 4.44 (1H, d, J=11.2 Hz, CH*H*Ph), 4.09 (2H, m, CH_2CH_3), 3.13 (1H, m, CHO), 2.76 (1H, m, $CHCO_2$Et), 1.97 (1H, m, $CH(CH_3)_2$), 1.78 (1H, ddd, J=13.9, 11.1, 2.7 Hz, CHC*H*HCH), 1.54 (3H, m), 1.23 (3H, t, J=7.0 Hz, CH_2CH_3), 1.20 (1H, m), 0.92 (3H, d, J=7.3 Hz, $CHCH_3$), 0.90 (6H, d, J=7.0 Hz, $CHCH_3$) and 0.87 (3H, d, J=7.3 Hz, $CHCH_3$); ^{13}C NMR (67.8 MHz) δ 176.6, 138.8, 128.2, 127.8, 127.3, 82.5, 72.2, 59.9, 42.8, 40.3, 33.9, 30.6, 26.2, 23.1, 22.2, 18.7, 17.2 and 14.4.

Compound 2,4-*anti*-**26**. ^{1}H NMR (270 MHz) δ 7.28 (5H, m, Ph), 4.52 (1H, d, J=11.2 Hz, C*H*HPh), 4.41 (1H, d, J=11.2 Hz, CH*H*Ph), 4.09 (2H, m, CH_2CH_3), 3.20 (1H, m, CHO), 2.67 (1H, m, $CHCO_2$Et), 1.97 (1H, m, $CH(CH_3)_2$), 1.78 (1H, ddd, J=13.9, 11.1, 2.7 Hz, CHC*H*HCH), 1.54 (3H, m), 1.20 (1H, m), 1.18 (3H, t, J=7.0 Hz, CH_2CH_3), 0.92 (3H, d, J=7.3 Hz, $CHCH_3$), 0.90 (6H, d, J=7.0 Hz, $CHCH_3$) and 0.86 (3H, d, J=7.3 Hz, $CHCH_3$); ^{13}C NMR (67.8 Hz) δ 176.6, 139.9, 128.3, 127.6, 127.2, 82.5, 72.1, 69.9, 42.0, 38.3, 31.3, 30.3, 23.1, 22.0, 20.6, 17.2 and 14.1

4.3.6. Compound 27 (2,4-*syn* and 2,4-*anti*). MS m/z 291 (M^+-i-Pr, 51%), 289 (7), 227 (7), 199 823), 181 (17), 158 (88), 130 (15), 101 (74) and 91 (100); HRMS calcd for $C_{18}H_{27}O_3$ [M^+-i-Pr,] 291.2029, found 291.1995.

Compound 2,4-*syn*-**27**. ^{1}H NMR (400 MHz) δ 7.30 (5H, m, Ph), 4.54 (1H, d, J=11.1 Hz, C*H*HPh), 4.47 (1H, d, J=11.1 Hz, CH*H*Ph), 4.08 (2H, m, CH_2CH_3), 3.09 (1H, m, CHO), 2.74 (1H, m, $CHCO_2$Et), 1.96 (1H, m, $CH(CH_3)_2$), 1.78 (2H, m, $CHCH_2CH$), 1.49 (2H, m, CH_2–*t*-Bu), 1.23 (3H, t, J=7.0 Hz, CH_2CH_3), 0.91 (3H, d, J=6.8 Hz, $CHCH_3$), 0.89 (3H, d, J=6.8 Hz, $CHCH_3$) and 0.88 (9H, s, *t*-Bu); ^{13}C NMR (67.8 MHz) δ 174.4, 138.9, 128.2, 127.8, 127.3, 82.4, 72.3, 60.0, 47.5, 38.8, 36.4, 31.0, 30.5, 29.5, 18.6, 17.2 and 14.3.

Compound 2,4-*anti*-**27**. ^{1}H NMR (400 MHz) δ 7.30 (5H, m, Ph), 4.54 (1H, d, J=11.1 Hz, C*H*HPh), 4.47 (1H, d, J=11.1 Hz, CH*H*Ph), 4.03 (2H, m, CH_2CH_3), 3.14 (1H, m, CHO), 2.52 (1H, m, $CHCO_2$Et), 1.96 (1H, m, $CH(CH_3)_2$), 1.78 (2H, m, $CHCH_2CH$), 1.30 (2H, m,

CH_2–*t*-Bu), 1.19 (3H, t, *J*=7.0 Hz, CH_2CH_3), 0.91 (3H, d, *J*=6.8 Hz, C*H*CH_3), 0.89 (3H, d, *J*=6.8 Hz, C*H*CH_3) and 0.83 (9H, s, *t*-Bu); ^{13}C NMR (100 MHz) δ 177.4, 138.9, 128.1, 127.5, 127.2, 81.8, 72.2, 60.0, 46.4, 39.2, 35.8, 30.9, 30.0, 29.5, 18.0, 17.2 and 14.2.

4.3.7. Compound 28 (2,4-*syn*). ^{1}H NMR (400 MHz) δ 7.39 (2H, d, *J*=7.1 Hz, Ph), 7.30–7.17 (11H, m, Ph), 7.01 (2H, m, Ph), 4.26 (1H, d, *J*=10.3 Hz, OC*H*HPh), 4.16–4.04 (4H, m, CH, C*H*OBn and CH_2CH3), 3.87 (1H, d, *J*=10.3 Hz, OCH*H*Ph), 2.72 (1H, m, C*H*CO_2Et), 1. 99 (1H, ddd, *J*=14.2, 11.5, 2.5 Hz, CHC*H*HCH), 1.50 (m, 2H), 1.25 (3H, t, *J*=7.1 Hz, $CO_2CH_2CH_3$), 1.33–1.15 (3H, m) and 0.83 (3H t, *J*=7.1 Hz, CH_2CH_3); ^{13}C NMR (100 MHz) δ 176.5, 142.4, 142.1, 138.1, 129.0 (2C), 128.5 (4C), 128.2 (2C), 128.1 (2C), 128.0 (2C), 127.4, 126.4, 126.3, 80.9, 73.6, 60.1, 57.3, 41.6, 36.6, 35.6, 20.5, 14.4 and 14.0; MS *m*/*z* 385 ($M^+-OC_2H_5$, 1%), 263(16), 167(24), 109(80) and 91(100); HRMS calcd for $C_{27}H_{29}O_2$ ($M^+-OC_2H_5$) 385.2167, found 385.2203.

4.3.8. Compound 29 (2,4-*syn*). ^{1}H NMR (400 MHz) δ 7.38 (2H, d, *J*=8.5 Hz, Ph), 7.30- 7.17(11H, m, Ph), 7.01 (2H, dd, *J*=7.5, 2.4 Hz, Ph), 4.28 (1H, d, *J*=10.0 Hz, OC*H*HPh), 4.17–4.00 (4H, m, CH, C*H*OBn and CH_2CH3), 3.87 (1H, d, *J*=10.0 Hz, OCH*H*Ph), 2.81 (1H, m, C*H*CO_2Et), 1.97 (1H, ddd, *J*=14.0, 11.8, 2.2 Hz, CHC*H*HCH), 1.52–1.40 (3H, m), 1.24 (3H, t, *J*=7.1 Hz, CH_2CH_3), 1.09 (1H, m), 0.85 (3H, d, *J*=6.3 Hz, $CHCH_3$) and 0.78 (3H, d, *J*=6.3 Hz, $CHCH_3$); ^{13}C NMR (100 MHz) δ 176.5, 142.4, 142.1, 138.1, 128.9 (2C), 128.5 (4C), 128.2 (2C), 128.1 (2C), 128.0 (2C), 127.4, 126.4, 126.3, 80.9, 73.6, 60.1, 57.3, 42.6, 39.9, 37.0, 26.0, 22.9, 22.2 and 14.4; MS *m*/*z* 399 ($M^+-OC_2H_5$, 2%), 277(61), 167(93) and 91(100); HRMS calcd for $C_{28}H_{31}O_2$ ($M^+-OC_2H_5$) 399.2324, found 399.2349.

4.3.9. Compound 30 (2,4-*syn*). ^{1}H NMR (400 MHz) δ 7.38–7.24 (5H, m, Ph), 4.51 (1H, d, *J*=11.0 Hz, C*H*HPh), 4.43 (1H, d, *J*=11.0 Hz, CH*H*Ph), 4.08 (1H, dq, *J*=10.7, 7.1 Hz, CO_2CHCH_3), 4.07 (1H, dq, *J*=10.7, 7.1 Hz, CO_2CHCH_3), 3.12 (1H, ddd, *J*=9.0, 5.1, 2.4 Hz, C*H*OBn), 2.66 (1H, dddd, *J*=11.3, 8.8, 5.4, 3.4 Hz, C*H*CO_2Et), 1.85 (1H, ddd, *J*=14.1, 11.3, 2.4 Hz, CHC*H*HCH), 1.76–1.51 (8H, m), 1.22 (3H, t, *J*=7.1 Hz, CH_2CH_3), 1.16–1.43 (6H, m), 1.07 (2H, m) and 0.89 (3H, t, *J*=7.1 Hz, CH_2CH_3), ^{13}C NMR (100 MHz) δ 176.4, 138.9, 128.2 (2C), 127.7 (2C), 127.3, 82.1, 72.3, 59.9, 42.0, 41.2, 35.8, 34.2, 29.2, 28.1, 26.8, 26.5, 26.4, 20.6, 14.4 and 14.1; MS *m*/*z* 301 ($M^+-OC_2H_5$, 5%), 263(54), 255(8), 236(8), 209(31), 171(24), 130(98), 101(28), 92(57) and 91(100); HRMS calcd for $C_{20}H_{29}O_2$ ($M^+-OC_2H_5$) 301.2167, found 301.2145.

4.3.10. Compound 31 (2,4-*syn*). ^{1}H NMR (400 MHz) δ 7.38–7.25 (5H, m, Ph), 4.52 (1H, d, *J*=11.0 Hz, C*H*HPh), 4.45 (1H, d, *J*=11.0 Hz, CH*H*Ph), 4.09 (1H, dq, *J*=10.8, 7.1 Hz, C*H*HCH_3), 4.07 (1H, dq, *J*=10.8, 7.1 Hz, CH*H*CH_3), 3.11 (1H, ddd, *J*=6.8, 5.1, 2.4 Hz, C*H*OBn), 2.74 (1H, m, C*H*CO_2Et), 1.82 (1H, ddd, *J*=13.9, 11.0, 2.4 Hz, CHC*H*HCH), 1.76–1.63 (6H, m), 1.60–1.50 (3H, m), 1.22 (3H, t, *J*=7.3 Hz, CH_2CH_3), 1.19–1.01 (6H, m), 0.90 (3H, d, *J*=6.3 Hz, $CHCH_3$) and 0.87 (3H, d, *J*=6.3 Hz, $CHCH_3$); ^{13}C NMR (100 MHz) δ 176.6, 138.9, 128.1 (2C), 127.7 (2C), 127.3, 82.1, 72.4, 59.9, 42.8, 41.3, 40.3, 34.7, 29.2, 28.1, 26.8, 26.5, 26.4, 26.2, 23.0, 22.2 and 14.4; MS *m*/*z* 315 ($M^+-OC_2H_5$, 5%), 277(55), 269(7), 250(9), 223(35), 185(27), 144(95), 101(50), 92(39) and 91(100); HRMS calcd for $C_{21}H_{31}O_2$ ($M^+-OC_2H_5$) 315.2324, found 315.2321.

4.3.11. Compounds 32 (2,4-*syn* and 2,4-*anti*). MS *m*/*z* 419 ($M^+-OC_2H_5$, 42%), 407 (100), 299 (97), 271 (75), 187 (58) and 91 (49); HRMS calcd for $C_{25}H_{43}O_3Si$ [$M^+-OC_2H_5$] 419.2981, found 419.2982.

Compound 2,4-*syn*-**32**. ^{1}H NMR (400 MHz) δ 7.37–7.25 (5H, m, Ph), 4.64 (1H, d, *J*=11.6 Hz, C*H*HPh), 4.37 (1H, d, *J*=11.6 Hz, CH*H*Ph), 3.95 (2H, m, CH_2CH_3), 3.50 (1H, m, CHO), 3.51 (1H, t, *J*=7.3 Hz, C*H*CHOTBDMS), 3.45 (1H, ddd, *J*=9.8, 2.7, 1.9 Hz, CHO), 2.52 (1H, m, C*H*CO_2Et), 1.73–1.50 (6H, m, $CH_2CH(CH_3)_2$, CH_2 and $CH(CH_3)_2$), 1.14 (3H, t, *J*=7.1 Hz, CH_2CH_3), 0.96 (3H, d, *J*=6.6 Hz, $CHCH_3$), 0.90 (9H, s, $C(CH_3)_3$), 0.88–0.79 (9H, $CH(CH_3)_2$ and $CHCH_3$), 0.07 (3H, s, $SiCH_3$) and 0.02 (3H, s, $SiCH_3$).

Compound 2,4-*anti*-**32**. ^{1}H NMR (400 MHz) δ 7.37–7.25 (5H, m, Ph), 4.63 (1H, d, *J*=11.2 Hz, C*H*HPh), 4.36 (1H, d, *J*=11.2 Hz, CH*H*Ph), 4.05 (2H, m, CH_2CH_3), 3.50 (1H, m, CHO), 3.50 (1H, t, *J*=7.3 Hz, C*H*CHOTBDMS), 3.36 (1H, td, *J*=6.4, 1.7 Hz, CHO), 2.74 (1H, m, C*H*CO_2Et), 2.00 (1H, ddd, *J*=13.5, 9.6, 2.3 Hz, CHC*H*HCH), 1.73–1.50 (5H, m, $CH_2CH(CH_3)_2$, CH*H* and $CH(CH_3)_2$), 1.20 (3H, t, *J*=7.1 Hz, CH_2CH_3), 0.95 (3H, d, *J*=6.6 Hz, $CHCH_3$), 0.89 (9H, s, $C(CH_3)_3$), 0.88–0.79 (9H, $CH(CH_3)_2$ and $CHCH_3$), 0.04 (3H, s, $SiCH_3$) and 0.02 (3H, s, $SiCH_3$).

4.3.12. Compound 33 (2,4-*syn*). ^{1}H NMR (400 MHz) δ 7.37–7.16 (10H, m, 2×Ph), 4.64 (1H, d, *J*=5.3 Hz, C*H*OTBDMS), 4.31 (1H, d, *J*=10.5 Hz, C*H*HPh), 4.19 (1H, d, *J*=10.5 Hz, CH*H*Ph), 4.02 (2H, m, CH_2CH_3), 3.43 (1H, m, C*H*OBn), 2.57 (1H, m, C*H*CO_2Et), 1.98 (1H, ddd, *J*=13.8, 11.5, 2.3 Hz, CHC*H*HCH), 1.63–1.41 (3H, m, CHCH*H*CH and CH_2), 1.16 (3H, t, *J*=7.2 Hz, OCH_2CH_3), 0.89 (9H, s, $C(CH_3)_3$), 0.86 (3H, t, *J*=7.2 Hz, CH_3), 0.04 (3H, s, $SiCH_3$) and −0.18 (3H, s, $SiCH_3$); ^{13}C NMR (67.8 MHz) δ 175.9, 142.3, 138.3, 128.12, 128.05, 127.8, 127.3, 127.2, 127.1, 82.8, 76.9, 73.4, 59.9, 43.5, 33.8, 26.5, 25.9, 18.3, 14.4, 11.8, −4.5 and −4.8; MS *m*/*z* 413 ($M^+-C_4H_9$, 2%), 249 (47), 221 (43), 107 (69) and 91 (100); HRMS calcd for $C_{24}H_{33}O_4Si$ [$M^+-C_4H_9$] 413.2148, found 413.2143.

4.3.13. Compound 34 (2,4-*syn*). ^{1}H NMR (400 MHz) δ 7.37–7.17 (10H, m, 2×Ph), 4.63 (1H, d, *J*=5.4 Hz, C*H*OTBDMS), 4.31 (1H, d, *J*=10.5 Hz, C*H*HPh), 4.19 (1H, d, *J*=10.5 Hz, CH*H*Ph), 4.02 (2H, m, CH_2CH_3), 3.41 (1H, m, C*H*OBn), 2.64 (1H, m, C*H*CO_2Et), 1.98 (1H, ddd, *J*=13.9, 11.5, 2.5 Hz, CHC*H*HCH), 1.58 (2H, m, CH_2), 1.36 (1H, m, CHCH*H*CH), 1.27 (2H, m, CH_2), 1.15 (3H, t, *J*=7.1 Hz, CH_3), 0.89 (9H, s, $C(CH_3)_3$), 0.87 (3H, t, *J*=7.3 Hz, CH_3), 0.04 (3H, s, $SiCH_3$) and −0.19 (3H, s, $SiCH_3$); ^{13}C NMR (67.8 MHz) δ 176.1, 142.3, 138.3, 128.13, 128.05, 127.8, 127.3, 127.2, 127.1, 82.9, 76.9, 73.5, 59.9, 41.7, 35.6, 34.2, 25.9, 20.6, 18.3, 14.4, 14.1, −4.5 and −4.8; MS *m*/*z* 469 (M^+-CH_3, 2%), 263 (66), 181 (98) and

91 (100); HRMS calcd for $C_{28}H_{41}O_4Si$ [M^+-CH_3] 469.2774, found 469.2799.

4.3.14. Compound 35 (2,4-*syn*). ^{1}H NMR (400 MHz) δ 7.34–7.17 (10H, m, 2×Ph), 4.63 (1H, d, J=5.4 Hz, C*H*OTBDMS), 4.31 (1H, d, J=10.5 Hz, C*H*HPh), 4.17 (1H, d, J=10.5 Hz, CH*H*Ph), 4.02 (2H, m, CH_2CH$_3$), 3.40 (1H, m, C*H*OBn), 2.74 (1H, m, C*H*CO$_2$Et), 1.96 (1H, ddd, J=13.9, 11.5, 2.3 Hz, CHC*H*HCH), 1.59–1.46 (3H, m, CHCH*H*CH and CH$_2$), 1.19 (1H, m, CH), 1.15 (3H, t, J=7.1 Hz, CH_2CH$_3$), 0.89 (9H, s, C(CH$_3$)$_3$), 0.87 (3H, d, J=6.6 Hz, C*H*CH$_3$), 0.84 (3H, d, J=6.4 Hz, CHCH_3), 0.04 (3H, s, SiCH$_3$) and −0.19 (3H, s, SiCH$_3$); ^{13}C NMR (67.8 MHz) δ 176.3, 142.3, 138.3, 128.2, 128.1, 127.8, 127.4, 127.2, 127.1, 82.9, 76.9, 73.5, 59.9, 42.5, 40.0, 34.7, 26.2, 25.9, 23.1, 22.1, 18.2, 14.3, −4.5 and −4.9; MS m/z 453 ($M^+-OC_2H_5$, 2%), 277 (87), 221 (66) and 91 (100); HRMS calcd for $C_{28}H_{41}O_3Si$ [$M^+-OC_2H_5$] 453.2825, found 453.2838.

4.3.15. Compound 36 (2,4-*syn*). ^{1}H NMR (400 MHz) δ 7.37–7.18 (10H, m, 2×Ph), 4.61 (1H, d, J=5.4 Hz, C*H*OTBDMS), 4.35 (1H, d, J=10.5 Hz, C*H*HPh), 4.15 (1H, d, J=10.5 Hz, CH*H*Ph), 4.00 (2H, q, J=7.1 Hz, CH_2CH$_3$), 3.35 (1H, m, C*H*OBn), 2.74 (1H, m, C*H*CO$_2$Et), 1.98 (1H, ddd, J=13.7, 11.5, 2.5 Hz, CHC*H*HCH), 1.77 (1H, dd, J=13.9, 10.0 Hz, C*H*H*t*-Bu), 1.54 (1H, ddd, J=13.7, 9.8, 3.7 Hz, CHCH*H*CH), 1.19 (1H, dd, J=13.9, 2.9 Hz, CH*Ht*-Bu), 1.15 (3H, t, J=7.1 Hz, CH$_2$CH_3), 0.89 (9H, s, C(CH$_3$)$_3$), 0.85 (3H, s, C(CH$_3$)$_3$), 0.04 (3H, s, SiCH$_3$) and −0.20 (3H, s, SiCH$_3$); ^{13}C NMR (67.8 MHz) δ 177.0, 142.3, 138.4, 128.3, 128.1, 128.0, 127.8, 127.7, 127.3, 127.2, 127.1, 82.9, 76.9, 73.5, 60.0, 47.3, 38.7, 37.2, 31.0, 29.5, 25.9, 18.2, 14.2, −4.5 and −4.8; MS m/z 467 ($M^+-OC_2H_5$, 2%), 221 (93) and 91 (100); HRMS calcd for $C_{29}H_{43}O_3Si$ [$M^+-OC_2H_5$] 467.2981, found 467.2994.

4.3.16. Compounds 37 (2,4-*syn*) and 44 (2,4-*syn*). MS m/z 429 ($M^+-OC_2H_5$, 1%), 158 (71) and 91 (100); HRMS calcd for $C_{29}H_{33}O_3$ [$M^+-OC_2H_5$] 429.2430, found 429.2435.

Compound **37**. ^{1}H NMR (400 MHz) δ 7.38–7.13 (15H, m, 3×Ph), 4.80–4.15 (5H, m, 2×CH_2Ph and CH*H*Ph), 4.09–3.95, (2H, m, CH_2CH$_3$), 3.54 (1H, ddd, J=9.3, 5.6, 2.4 Hz, C*H*OBn), 2.74 (1H, m, C*H*–CO$_2$Et), 2.02 (1H, ddd, J=13.7, 11.0, 2.3 Hz, CHC*H*HCH), 1.65–1.35 (5H, m, CH$_2$*i*-Pr, CH*H* and CH(CH$_3$)$_2$), 1.14 (3H, t, J=7.1 Hz, CH$_2$CH_3), 0.86 (3H, d, J=6.4 Hz, CH$_3$) and 0.84 (3H, d, J=6.6 Hz, CH$_3$).

Compound **44**. ^{1}H NMR (400 MHz) δ 7.38–7.13 (15H, m, 3×Ph), 4.80–4.15 (5H, m, 2×CH_2Ph and CH*H*Ph), 4.09–3.95, (2H, m, CH_2CH$_3$), 3.64 (1H, ddd, J=10.2, 6.6, 2.7 Hz, C*H*OBn), 2.74 (1H, m, C*H*–CO$_2$Et), 1.65–1.35 (6H, m, CH$_2$*i*-Pr, CH$_2$ and CH(CH$_3$)$_2$), 1.17 (3H, t, J=7.1 Hz, CH$_2$CH_3), 0.84 (3H, d, J=6.3 Hz, CH$_3$) and 0.80 (3H, d, J=6.3 Hz, CH$_3$).

4.3.17. Compounds 38 (2,4-*syn*) and 45 (2,4-*syn*). MS m/z 367 (M^+-OCH_3, 5%), 271 (99), 121 (100), 181 (39) and 91 (77); HRMS calcd for $C_{24}H_{31}O_3$ [M^+-OCH_3] 367.2273, found 367.2276.

Compound **38**. ^{1}H NMR (400 MHz) δ 7.35–7.17 (10H, m, 2×Ph), 4.37 (1H, d, J=10.7 Hz, C*H*HPh), 4.21 (1H, d, J=10.7 Hz, CH*H*Ph), 4.16 (1H, d, J=5.4 Hz, C*H*OCH$_3$), 4.04 (2H, m, CH_2CH$_3$), 3.47 (1H, m, C*H*OBn), 3.25 (3H, s, OCH$_3$), 2.73 (1H, m, C*H*–CO$_2$Et), 1.96 (1H, ddd, J=13.9, 11.5, 2.4 Hz, CHC*H*HCH), 1.15 (3H, t, J=7.1 Hz, CH$_2$CH_3), 0.87 (3H, d, J=6.3 Hz, CH(CH_3)$_2$) and 0.84 (3H, d, J=6.4 Hz, CH(CH_3)$_2$).

Compound **45**. ^{1}H NMR (400 MHz) δ 7.35–7.17 (10H, m, 2×Ph), 4.67 (1H, d, J=10.7 Hz, C*H*HPh), 4.49 (1H, d, J=10.7 Hz, CH*H*Ph), 4.18 (1H, d, J=5.9 Hz, C*H*OCH$_3$), 4.04 (2H, m, CH_2CH$_3$), 3.57 (1H, m, C*H*OBn), 3.26 (3H, s, OCH$_3$), 2.73 (1H, m, C*H*–CO$_2$Et), 1.20 (3H, t, J=7.1 Hz, CH$_2$CH_3), 0.84 (3H, d, J=6.4 Hz, CH(CH_3)$_2$) and 0.80 (3H, d, J=6.1 Hz, CH(CH_3)$_2$).

4.3.18. Compound 39 (2,4-*syn*). ^{1}H NMR (400 MHz) δ 7.34–7.17 (5H, m, Ph), 4.56 (1H, d, J=11.2 Hz, C*H*HPh), 4.42 (1H, d, J=11.2 Hz, CH*H*Ph), 4.00 (2H, m, CH_2CH$_3$), 3.41 (1H, t, J=5.0 Hz, C*H*OTBDMS), 3.24 (1H, ddd, J=10.5, 5.0, 2.0 Hz, C*H*OBn), 2.66 (1H, m, C*H*CO$_2$Et), 1.86 (1H, ddd, J=13.9, 10.8, 1.9 Hz, CHC*H*HCH), 1.75 (1H, m, C*H*(CH$_3$)$_2$), 1.59–1.43 (3H, m, CH*H* and CH$_2$), 1.15 (3H, t, J=7.2 Hz, CH$_2$CH_3), 0.88 (3H, d, J=6.8 Hz, CH$_3$), 0.83 (9H, s, C(CH$_3$)$_3$), 0.82 (3H, d, J=7.1 Hz, CH$_3$), 0.79 (3H, d, J=6.6 Hz, CH$_3$), −0.04 (3H, s, SiCH$_3$) and −0.08 (3H, s, SiCH$_3$); MS m/z 419 ($M^+-OC_2H_5$, 4%),271 (44), 187 (94) and 91 (100); HRMS calcd for $C_{25}H_{43}O_3Si$ [$M^+-OC_2H_5$] 419.2981, found 419.2982.

4.3.19. Compound 40 (2,4-*syn*). ^{1}H NMR (400 MHz) δ 7.40–7.24 (10H, m, 2×Ph), 4.77 (1H, d, J=11.2 Hz, C*H*HPh), 4.75 (1H, d, J=5.1 Hz, C*H*OTBDMS), 4.55 (1H, d, J=11.2 Hz, CH*H*Ph), 4.06 (2H, s, J=7.1 Hz, CH_2CH$_3$), 3.51 (1H, ddd, J=10.5, 5.4, 2.2 Hz, C*H*OBn), 2.52 (1H, m, C*H*CO$_2$Et), 1.68 (1H, ddd, J=13.7, 11.4, 2.2 Hz, CHC*H*HCH), 1.53 (1H, m, C*H*HCH$_3$), 1.25 (1H, m, CH*H*CH$_3$), 1.22 (1H, m, CHC*H*HCH), 1.20 (3H, t, J=7.1 Hz, OCH$_2$CH_3), 0.87 (9H, s, C(CH$_3$)$_3$), 0.80 (3H, t, J=7.4 Hz, CH$_3$), 0.02 (3H, s, SiCH$_3$) and −0.15 (3H, s, SiCH$_3$); ^{13}C NMR (67.8 MHz) δ 175.9, 141.3, 138.6, 128.2, 128.1, 127.7, 127.5, 127.2, 127.0, 81.9, 76.3, 73.8, 59.9, 43.5, 33.4, 26.3, 25.89, 25.88, 18.2, 14.4, 11.9, −4.7 and −4.9; MS m/z 425 ($M^+-OC_2H_5$, 3%), 413 (4), 249 (58), 221 (51), 121 (56) and 91 (100); HRMS calcd for $C_{26}H_{37}O_3Si$ [$M^+-OC_2H_5$] 425.2512, found 425.2495.

4.3.20. Compound 41 (2,4-*syn*). ^{1}H NMR (400 MHz) δ 7.40–7.24 (10H, m, 2×Ph), 4.77 (1H, d, J=11.0 Hz, C*H*HPh), 4.74 (1H, d, J=5.4 Hz, C*H*OTBDMS), 4.55 (1H, d, J=11.0 Hz, CH*H*Ph), 4.05 (2H, d, J=7.1 Hz, CH_2CH$_3$), 3.50 (1H, ddd, J=10.2, 5.4, 2.4 Hz, C*H*OBn), 2.58 (1H, m, C*H*CO$_2$Et), 1.67 (1H, ddd, J=12.7, 11.2, 2.4 Hz, CHC*H*HCH), 1.51 (1H, m, C*H*H), 1.30–1.15 (4H, m, CH*H* and CH$_2$), 1.19 (3H, q, J=7.1 Hz, CH_2CH$_3$), 0.87 (9H, s, C(CH$_3$)$_3$), 0.82 (3H, t, J=7.2 Hz, CH$_3$), 0.16 (3H, s, SiCH$_3$) and −0.15 (3H, s, SiCH$_3$); ^{13}C NMR (67.8 MHz) δ 176.1, 141.3, 138.6, 128.2, 128.1, 127.7, 127.5, 127.2, 127.0, 81.9, 76.3, 73.9, 59.9, 41.7, 35.4, 33.8, 25.9, 20.6, 18.2, 14.4, 14.0, −4.7 and −4.9; HRMS calcd for $C_{27}H_{39}O_3Si$ [$M^+-OC_2H_5$] 439.2668, found 439.2637.

4.3.21. Compound 42 (2,4-*syn*). ^{1}H NMR (400 MHz) δ 7.41–7.24 (10H, m, 2×Ph), 4.79 (1H, d, J=11.0 Hz, C*H*HPh), 4.73 (1H, d, J=5.6 Hz, CHOTBDMS), 4.56 (1H, d, J=11.0 Hz, CH*H*Ph), 4.05 (2H, q, J=7.1 Hz, CH_2CH$_3$), 3.48 (1H, m, C*H*OBn), 2.67 (1H, m, C*H*CO$_2$Et), 1.64 (1H, ddd, J=13.4, 11.2, 2.0 Hz, CHC*H*HCH), 1.54–1.38 (2H, m, CH$_2$), 1.19 (3H, t, J=7.1 Hz, CH$_2$CH_3), 1.05 (1H, m, CH(CH$_3$)$_2$), 0.88 (9H, s, C(CH$_3$)$_3$), 0.82 (3H, d, J=6.6 Hz, CHCH_3), 0.79 (3H, d, J=6.4 Hz, CHCH_3), 0.02 (3H, s, SiCH$_3$) and −0.15 (3H, s, SiCH$_3$); ^{13}C NMR (67.8 MHz) δ 176.2, 141.3, 138.6, 128.2, 128.1, 127.7, 127.4, 127.2, 127.0, 82.1, 76.4, 73.9, 59.9, 42.4, 40.1, 34.4, 26.2, 25.9, 23.1, 22.1, 18.3, 14.4, −4.6 and −4.8; MS m/z 453 (M$^+$−OC$_2$H$_5$, 2%), 277 (92), 221 (85) and 91 (100); HRMS calcd for C$_{28}$H$_{41}$O$_3$Si [M$^+$−OC$_2$H$_5$] 453.2825, found 453.2823.

4.3.22. Compound 43 (2,4-*syn*). ^{1}H NMR (400 MHz) δ 7.43–7.23 (10H, m, 2×Ph), 4.80 (1H, d, J=11.0 Hz, C*H*HPh), 4.73 (1H, d, J=5.6 Hz, C*H*OTBDMS), 4.60 (1H, d, J=11.9 Hz, CH*H*Ph), 4.05 (2H, q, J=7.1 Hz, CH_2CH$_3$), 3.43 (1H, m, C*H*OBn), 2.67 (1H, m, C*H*CO$_2$Et), 1.70 (2H, m, CH$_2$), 1.25–1.00 (2H, m, CH$_2$), 1.20 (3H, t, J=7.1 Hz, CH_2CH$_3$), 0.88 (9H, s, C(CH$_3$)$_3$), 0.80 (3H, s, C(CH$_3$)$_3$), 0.02 (3H, s, SiCH$_3$) and −0.15 (3H, s, SiCH$_3$); ^{13}C NMR (100.4 MHz) δ 177.1, 141.2, 138.7, 128.2, 128.1, 127.7, 127.5, 127.2, 127.0, 82.1, 76.0, 73.9, 60.1, 47.2, 38.5, 36.6, 30.9, 29.5, 25.9, 18.2, 14.2, −4.7 and −4.9; MS m/z 467 (M$^+$−OC$_2$H$_5$, 2%), 291 (79), 221 (68) and 91 (100); HRMS calcd for C$_{29}$H$_{43}$O$_3$Si [M$^+$−OC$_2$H$_5$] 467.2981, found 467.2992.

4.4. Determination of the diastereomer ratios and stereochemistries

4.4.1. δ-Hydroxy ester 64. ^{1}H NMR (400 MHz) δ 7.35–7.26 (10H, m, 2×Ph), 4.95 (1H, d, J=4.1 Hz, C*H*OH), 4.54 (2H, s, CH_2Ph), 4.00 (2H, m, CH_2CH$_3$), 3.58 (1H, m, C*H*OBn), 2.72 (1H, m, C*H*CO$_2$Et), 1.14 (3H, t, J=7.1 Hz, CH_2CH$_3$), 0.86 (3H, d, J=6.4 Hz, C*H*CH$_3$) and 0.83 (3H, d, J=6.1 Hz, CHCH_3).

4.4.2. δ-Lactones 65 and 66. *Compound* **65**. ^{1}H NMR (400 MHz) δ 7.42–7.06 (5H, m, Ph), 5.22 (1H, d, J=8.1 Hz, δ-H), 4.35 (1H, d, J=11.7 Hz, C*H*HPh), 4.25 (1H, d, J=11.7 Hz, CH*H*Ph), 3.75 (1H, m, γ-H), 2.59 (1H, m, α-H), 2.29 (1H, ddd, J=13.4, 6.8, 4.4 Hz, β-H), 1.91 (1H, ddd, J=13.9, 9.3, 4.9 Hz, C*H*H*i*-Pr), 1.75 (2H, m, β-H and C*H*(CH$_3$)$_2$), 1.51 (1H, ddd, J=13.9, 9.2, 5.2 Hz, CH*Hi*-Pr), 0.95 (3H, d, J=6.6 Hz, CHCH_3) and 0.88 (3H, d, J=6.6 Hz, CHCH_3); MS m/z 281 (M$^+$−CH$_2$CH(CH$_3$)$_2$, 4%), 247 (M$^+$−C$_7$H$_7$, 13), 141 (97) and 91 (100); HRMS calcd for C$_{15}$H$_{19}$O$_3$ (M$^+$−C$_7$H$_7$) 247.1334, found 247.1345.

Compound **66**. ^{1}H NMR (400 MHz) δ 7.41–7.06 (5H, m, Ph), 5.34 (1H, d, J=6.3 Hz, δ-H), 4.46 (1H, d, J=11.7 Hz, C*H*HPh), 4.36 (1H, d, J=11.7 Hz, CH*H*Ph), 3.81 (1H, m, γ-H), 2.87 (1H, m, α-H), 2.14 (1H, ddd, J=14.2, 6.8, 3.9 Hz, β-H), 1.88 (1H, ddd, J=14.2, 9.1, 5.2 Hz, C*H*H*i*-Pr), 1.72 (2H, m, β-H and C*H*(CH$_3$)$_2$), 1.32 (1H, ddd, J=14.2, 8.6, 5.9 Hz, CH*Hi*-Pr), 0.95 (3H, d, J=6.6 Hz, CHCH_3) and 0.92 (3H, d, J=6.6 Hz, CHCH_3).

4.4.3. γ-Hydroxy ester 67. ^{1}H NMR (400 MHz) δ 7.44–7.33 (5H, m, Ph), 4.01 (1H, d, J=5.1 Hz, C*H*OTBDMS), 4.19 (2H, m, CH_2CH$_3$), 3.73 (1H, m, C*H*OH), 2.74 (1H, m, C*H*CO$_2$Et), 1.30 (3H, q, J=7.1 Hz, CH_2CH$_3$), 1.15 (3H, t, J=7.1 Hz, CH$_3$), 0.97 (9H, s, C(CH$_3$)$_3$), 0.94 (3H, t, J=7.3 Hz, CH$_2$CH$_3$), 0.11 (3H, s, SiCH$_3$) and −0.09 (3H, s, SiCH$_3$).

4.4.4. γ-Lactone 68. ^{1}H NMR (400 MHz) δ 7.40–7.25 (5H, m, Ph), 5.04 (1H, d, J=2.4 Hz, C*H*Ph), 4.51 (1H, dt, J=8.5, 3.0 Hz, γ-H), 2.70 (1H, m, α-H), 2.43 (1H, ddd, J=13.0, 9.8, 3.5 Hz, β-H), 1.79 (1H, m, C*H*H), 1.57 (1H, dt, J=13.0, 8.6 Hz, β-H), 1.43–1.28 (3H, m, CH*H* and CH$_2$), 0.91 (3H, t, J=6.8 Hz, CH$_3$), 0.90 (9H, s, C(CH$_3$)$_3$), 0.08 (3H, s, SiCH$_3$) and −0.08 (3H, s, SiCH$_3$); MS m/z 291 (M$^+$−t-Bu, 81%) and 221 (100); HRMS calcd for C$_{16}$H$_{23}$O$_3$Si (M$^+$−t-Bu) 291.1417, found 291.1425.

4.4.5. δ-Hydroxy ester 69. ^{1}H NMR (400 MHz) δ 7.38–7.25 (10H, m, 2×Ph), 4.63 (1H, d, J=4.1 Hz, C*H*OH), 4.54 (1H, d, J=10.7 Hz, C*H*HPh), 4.38 (1H, d, J=10.7 Hz, CH*H*Ph), 4.04 (2H, m, CH_2CH$_3$), 3.59 (1H, m, C*H*OBn), 2.67 (1H, m, C*H*CO$_2$Et), 1.17 (3H, t, J=7.1 Hz, CH$_2$CH_3), 0.88 (3H, d, J=6.3 Hz, CHCH_3) and 0.84 (3H, d, J=6.4 Hz, CHCH_3).

4.4.6. δ-Lactone 70. ^{1}H NMR (400 MHz) δ 7.44–6.91 (5H, m, Ph), 5.32 (1H, d, J=2.0 Hz, δ-H), 4.26 (1H, d, J=12.2 Hz, C*H*HPh), 4.12 (1H, d, J=12.2 Hz, CH*H*Ph), 3.94 (1H, dt, J=6.8, 2.8 Hz, γ-H), 2.59 (1H, m, α-H), 2.45 (1H, ddd, J=14.2, 8.6, 7.2 Hz, β-H), 1.90 (1H, C*H*H*i*-Pr), 1.77 (1H, m, CH(CH$_3$)$_2$), 1.71 (1H, ddd, J=14.2, 10.5, 3.4 Hz, β-H), 1.39 (1H, m, C*H*H), 0.95 (3H, d, J=6.6 Hz, CHCH_3) and 0.92 (3H, d, J=6.6 Hz, CHCH_3); ^{13}C NMR (100.4 MHz) δ 174.3, 137.4, 136.0, 128.2, 128.1, 128.06, 128.0, 127.4, 127.3, 126.7, 80.5, 74.0, 71.2, 40.1, 35.2, 31.6, 25.0, 23.2 and 21.7; MS m/z 281 (M$^+$−CH$_2$CH(CH$_3$)$_2$, 1%), 247 (M$^+$−C$_7$H$_7$, 15), 141 (100) and 91 (76); HRMS calcd for C$_{15}$H$_{19}$O$_3$ (M$^+$−C$_7$H$_7$) 247.1334, found 247.1345.

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