Chiral Carbanions, 1

Configurational Stability and Reactions of α-Acyloxy-Substituted α-Methylbenzyllithium Compounds

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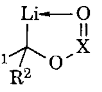
Racemic and optically active 1-phenylethyl esters of pivalic, (−)-camphanic and 2,4,6-triisopropylbenzoic acid were prepared. The esters **7a** of pivalic acid were deprotonated with lithium 2,2,6,6-tetramethylpiperidide (Li-TMP) to form α-oxy-α-methylbenzyllithium compounds which are partly configurationally stable prior to acylation with starting material. Camphanic ester (−)-**7b** cannot be deprotonated by Li-TMP and *t*BuLi is added to the ester function to afford ketone (−)-**12a**. 1-Phenylethyl 2,4,6-triisopropylbenzoates **16** were transformed within minutes to carbanions **19** by using *s*BuLi/TMEDA in THF, hexane, toluene and *s*BuLi without TMEDA in toluene/20% diethyl ether at −78 °C. The carbanions are configurationally stable only in toluene/20% diethyl ether and racemise partly in the other solvents. They react with a variety of electrophiles with either retention [MeOD, AcOD, $(MeO)_2CO$, $ClCO_2Me$] or inversion (Me_3SnCl) of configuration. Carbanions **19** rearrange on warming to −20 °C to hydroxy ketone **24** with racemisation.

Chiral carbanions with heteroatom-containing substituents have been investigated intensively during the last few years[1]. Their configurational stability has attracted much attention since Still's discovery of non-racemic α-oxy-substituted organolithium compounds[2]. Dipole-stabilized α-oxycarbanions of the general structure **1** have been prepared for synthetic and mechanistic reasons[3]. A common structural feature of compounds **1a**–**1c** is the intramolecular complexation of a lithium center by a C=O or P=O dipole whereby a five-membered chelate ring is formed. Carbamoyloxy-substituted carbanions **1a** have been introduced by Hoppe et al. and have proven very valuable due to their highly enantioselective preparation and configurational stability at −78 °C for R^1 = H and R^2 = alkyl[4]. An X-ray crystal structure of a chiral, carbamoyloxy-substituted allyllithium proves that the tetracoordinated lithium is part of a five-membered chelate ring[5]. They react readily with a variety of electrophiles.



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	X
a	CNR_2
b	$P(OR)_2$
c	CR

Phosphoryloxy-substituted carbanions **1b** are obtained by deprotonation of benzyl phosphates with *n*BuLi and LDA. Carbanions stabilized by a P=O instead of a C=O dipole are reactive intermediates in the phosphate–phosphonate rearrangement, and the reverse process, the phosphonate–phosphate rearrangement (Scheme 1)[6]. This isomerisation may proceed in either direction, depending on the reaction conditions, and affords either 1-hydroxyphosphonates **4** or phosphates **2**. In an α-phosphoryloxy-alkyllitihium compound the carbanion attacks the electrophilic phosphorus to form a pentacoordinated species which gives the lithium salt **3** of α-hydroxyphosphonate **4**, corresponding to an intramolecular acylation. This rearrangement is prevented at −78 °C in the case of carbamates **1a** by a reduced electrophilicity of the C=O group and steric shielding by bulky substituents (R = *i*Pr or R_2N is a cyclic α,α′-tetrasubstituted amine). A rearrangement analogous to the phosphate–phosphonate rearrangement has been mentioned in the literature to occur at higher temperatures for carbanions **1a**, but has not been investigated more closely[7], except for benzoates[8]. Carbanions **1a** and **1b** with R^1 = Ph and R^2 = Me are configurationally stable, but only **1b** rearranges whereby the configuration at the benzylic centre is retained during the short lifetime of the carbanion prior to the isomerisation[9].

Carbanions of type **1c** with a shielded carbonyl group, such as 2,4,6-triisopropylbenzoate esters describd by Beak et al., are more similar to carbanions of type **1b** than to those of the type **1a**[10]. Their configurational stability has not yet been investigated.

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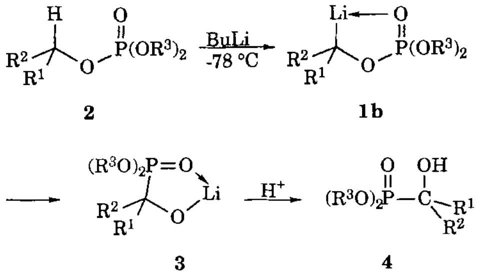
Scheme 1



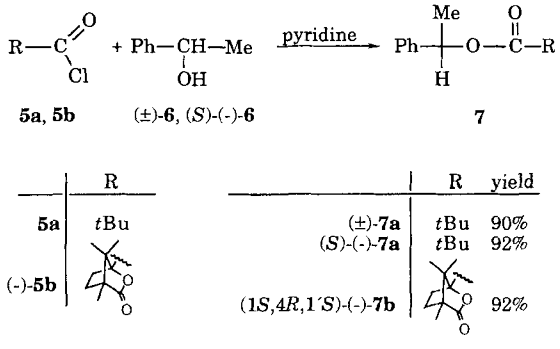
Synthesis, Reactions and Configurational Stability of Carbanions Derived from 1-Phenylethyl Esters of Pivalic and Camphanic Acid

We decided to study the configurational stability of α-methylbenzyl carbanions with an α-acyloxy substituent and chose 1-phenylethyl esters, as comparative investigations with carbamoyloxy and phosphoryloxy substituents instead of the acyloxy group are already known. The configurational stability of a variety of benzyllithium compounds has been tested by Hoffmann et al. who determined the rate of racemisation relative to the rate of addition to a chiral aldehyde[11]. Crystal structures of benzyllithium compounds reveal a flattened tetrahedral, but not a planar arrangement of substituents at the carbanionic carbon atom[12].

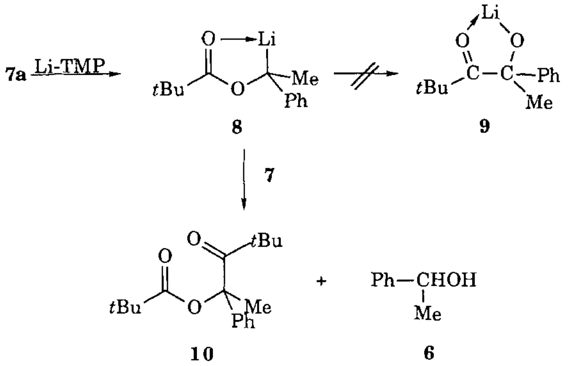
Esters can, in principle, be deprotonated by strong bases either in α position to the carbonyl function of the parent acid or the oxygen atom of the alcohol, the former hydrogen being much more acidic than the latter one. In order to abstract the proton in α position to the oxygen atom and to prevent addition of the base (nucleophile) to the carbonyl function, esters containing no α-hydrogen atoms and a shielded C=O have to be used. Furthermore, bulky bases such as lithium 2,2,6,6-tetramethylpiperidide (Li-TMP) are recommended for deprotonation if benzylic esters are involved[8].

Pivaloyl chloride (**5a**) and (−)-camphanoyl chloride (**5b**) were treated with racemic and optically active (93% ee) 1-phenylethanol (**6**) in dry pyridine to afford the esters **7a** and **7b** (Scheme 2). When pivaloate (±)-**7a** was treated with LDA in THF at −78 °C for 2 h and subsequently with D_2O, only starting material containing no deuterium was recovered in 60% yield. This experiment shows that LDA as base is too weak to remove a benzylic hydrogen atom. When Li-TMP was used instead of LDA, the keto ester **10** was isolated as the reaction product in 92% yield (Scheme 3). Its formation implies that the dipole-stabilized carbanion (±)-**8** is generated in situ. It is chemically not stable and reacts immediately with starting material. The intramolecular attack of the benzylic carbanion on the carbonyl function does not seem to occur (ester−hydroxy ketone rearrangement). The allignment of the carbanion in a plane perpendicular to the sp^2-hybridized carbon atom, forming an angle of 105°[13] with the C=O group, cannot be realised easily, because it is an intramolecular process. This contrasts with the ease of the phosphate−phosphonate rearrangement, where a tetracoordinated phosphorus atom is easily attacked intramolecularly by a carbanion.

Scheme 2

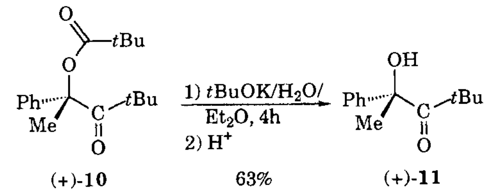


Scheme 3



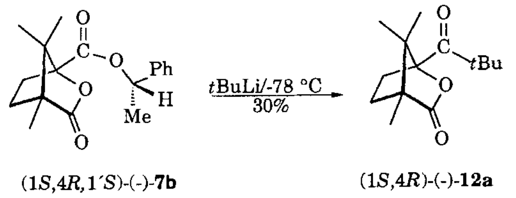
When the optically active ester (S)-(−)-**7a** was treated in the same way as the racemic ester (±)-**7a**, the optically active keto ester (+)-**10** was isolated. The intermediate pivaloyloxy-substituted carbanion (S)-**8** must therefore at least partly retain its stereochemistry. To determine the enantiomeric excess of keto ester (+)-**10**, it was saponified[14] with tBuOK/stoichiometric amount of water in diethyl ether to the corresponding hydroxy ketone (+)-**11** (Scheme 4). Its enantiomeric excess as determined by medium pressure liquid chromatography[15,29] on cellulose triacetate was 20%. For reasons of plausibility we assume that the benzyl carbanion (S)-**8** formed on deprotonation of ester (S)-(−)-**7a** is acylated with retention of configuration. Hoppe et al. found that the same α-oxy-α-methylbenzyl carbanion with a carbamoyl instead of a pivaloyl group reacts with electrophiles such as CO_2, diethyl carbonate, methyl chloroformate, carboxylic acid derivatives, chlorotrimethylsilane, and chlorotrimethylstannane[16]. Retention or inversion of configuration predominates, depending on the electrophile used. Here the carbonyl group of the starting material is not shielded efficiently enough to prevent a reaction with the carbanion, which can be generated by deprotonation, but cannot be brought to reaction with externally added electrophiles.

Scheme 4



The camphanic ester (−)-**7b** having no α-hydrogen atom in the acid part of the molecule was investigated next. It contains an additional ester function for complexation, which might influence the ratio of products formed. Surprisingly, Li-TMP did not deprotonate at the benzylic position at −78 °C. *t*BuLi adds to the carbonyl function, which is not shielded enough, to form ketone (−)-**12a** (Scheme 5).

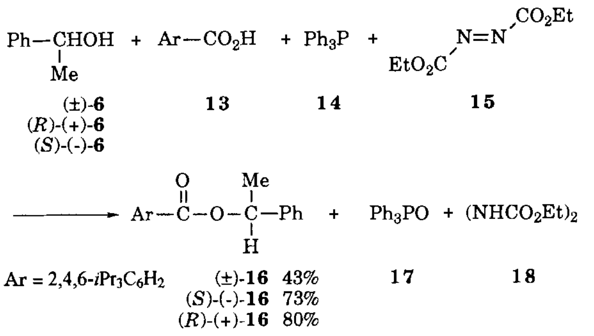
Scheme 5



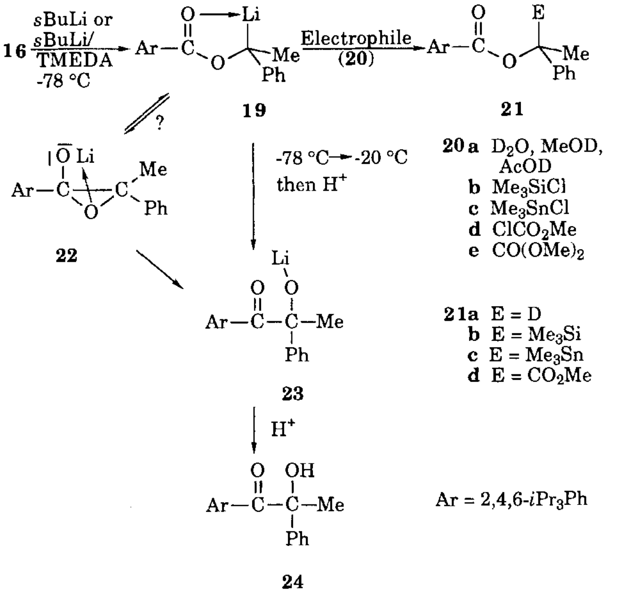
Synthesis, Configurational Stability and Reactions of Carbaions Derived from 1-Phenylethyl Esters of 2,4,6-Triisopropylbenzoic Acid

Benzoates with isopropyl or *tert*-butyl groups at C-2 and C-6 disfavour nucleophilic additions to the carbonyl group. Esters of methanol and primary alcohols are deprotonated by *s*BuLi/TMEDA in THF as found by Beak et al.[10] We therefore prepared optically active (ee ≥ 97%) esters of 2,4,6-triisopropylbenzoic acid by the Mitsunobu reaction and studied the configurational stability of their corresponding organolithium compounds (Scheme 6). This esterification causes inversion of configuration. As the optically active starting 1-phenylethanols had ee values of ≥ 97%, the benzoates **16** should have opposite configuration and the same ee value. First, the deprotonation was investigated at −78 °C in various solvents with an excess of *s*BuLi with and without an equivalent amount of TMEDA as bidentate ligand. After a specified time the reaction was quenched with D_2O, MeOD or AcOD (Scheme 7). The deuterated starting materials were isolated and, if optically active ones were used, their optical rotations were measured and the extent of deuteration was determined by ^{1}H-NMR spectroscopy.

Scheme 6



Scheme 7



Racemic 2,4,6-triisopropylbenzoate (±)-**16** was deprotonated in toluene by *s*BuLi/TMEDA quantitatively within 30 min (Table 1, entry 1). The use of *s*BuLi in toluene/10% diethyl ether yielded at reaction times of 5 and 15 min products containing 47 or 73% deuterium, respectively (entries 2 and 3). Optically active 2,4,6-triisopropylbenzoate (+)-**16** was not deprotonated in toluene by *s*BuLi without added TMEDA (entry 4). The carbanion was generated in toluene/10% diethyl ether by *s*BuLi to the extent of 81% and treated with deuterated methanol or acetic acid with retention of configuration, the ee values being 74 and 70% (entries 5 and 6). In THF as solvent carbanion **19** was formed quantitatively within 30 min and racemises completely (entry 7). When the deprotonation was carried out in hexane as nonpolar solvent, the proton abstraction was finished within two minutes and the extent of racemisation increased with increasing reaction time prior to quenching (entries 8, 9, 10). These experiments demonstrate that 2,4,6-triisopropylbenzoyloxy-substituted α-methylbenzyllithium **19** can be formed easily with *s*BuLi/TMEDA, but it racemises completely in THF and partly in hexane. It is configurationally less stable than the corresponding *N*,*N*-diisopropylcarba-

Table 1. Deprotonation of 2,4,6-triisopropylbenzoates **16** and reaction of corresponding α-methyl-α-oxybenzyllithium compounds with electrophiles

Entry	Starting compd.[a]	Solvent	Base[b]	*t* (min)	Electrophile	Product	Yield (%)[c]	D (%)[d]	$[\alpha]_D^{20}$ (*c*)[e]	ee (%)[f]
1	(±)-**16**	Tol.[g]	*s*BuLi/TMEDA	30	MeOD	**21a**	83	97	-	-
2	(±)-**16**	Tol./10% Et$_2$O	*s*BuLi	5	MeOD	**21a**	94	47	-	-
3	(±)-**16**	Tol./10% Et$_2$O	*s*BuLi	15	MeOD/Tol. (1:1)	**21a**	93	73	-	-
4	(+)-**16**	Toluene	*s*BuLi	120	MeOD	(+)-**16**	92	0	+18.2 (1.1)	≥98
5	(+)-**16**	Tol./10% Et$_2$O	*s*BuLi	30	MeOD/Tol. (1:1)	**21a**	97	81	+12.6 (1.5)	74
6	(+)-**16**	Tol./10% Et$_2$O	*s*BuLi	30	AcOD/Tol. (1:1)	**21a**	92	78	+11.8 (0.8)	70
7	(+)-**16**	THF	*s*BuLi/TMEDA	30	D$_2$O	**21a**	66	90	+0.3 (1.2)	<1
8	(+)-**16**	Hexane	*s*BuLi/TMEDA	30	MeOD	**21a**	79	100	+5.4 (1.2)	32
9	(-)-**16**	Hexane	*s*BuLi/TMEDA	5	MeOD	**21a**	73	100	-7.6 (0.8)	44
10	(-)-**16**	Hexane	*s*BuLi/TMEDA	2	MeOD	**21a**	78	100	-11.2 (1.3)	65
11	(-)-**16**	Hexane	*s*BuLi/TMEDA	2	Me$_3$SiCl	**21b**	54	-	+19.5 (1.2)	-
12	(-)-**16**	Hexane	*s*BuLi/TMEDA	2	Me$_3$SnCl	**21c**	83	-	+8.8 (1.2)	22[h]
13	(-)-**16**	Hexane	*s*BuLi/TMEDA	2	ClCO$_2$Me	**21d**	44	-	+1.3 (1.5)	46
14	(-)-**16**	Hexane	*s*BuLi/TMEDA	2	(MeO)$_2$CO	**21d**	44	-	+1.1 (1.6)	39
15	(-)-**16**	Tol./20% Et$_2$O	*s*BuLi	5	AcOD	**21a**	74	65	-20.2 (3.0)	≥98
16	(-)-**16**	Tol./20% Et$_2$O	*s*BuLi	10	AcOD	**21a**	85	94	-18.8 (2.9)	95
17	(-)-**16**	Tol./20% Et$_2$O	*s*BuLi	60	AcOD	**21a**	84	100	-18.0 (6.8)	91
18	(+)-**16**	Tol./20% Et$_2$O	*s*BuLi	10	Me$_3$SnCl	**21c**	51	-	-40.8 (5.2)	≥98
19	(-)-**16**	Tol./20% Et$_2$O	*s*BuLi	10	ClCO$_2$Me	**21d**	61	-	+2.7 (1.2)	93[i]
20	(-)-**16**	Tol./20% Et$_2$O	*s*BuLi	10	(MeO)$_2$CO	**21d**	53	-	+1.6 (1.3)	78[i]
21	(±)-**16**	Tol./20% Et$_2$O	*s*BuLi	10	Me$_3$SnCl	**21c**	52	-	-	-
22	(±)-**16**	Tol./20% Et$_2$O	*s*BuLi	10	ClCO$_2$Me	**21d**	42	-	-	-

[a] All reactions were carried out with 1 mmol of substrate at −78 °C. − [b] *s*BuLi/TMEDA were used in stoichiometric amounts; 2.0 mmol for 1.0 mmol of substrate. − [c] Refers to products purified by flash chromatography. − [d] Deuterium contents as determined by ^{1}H-NMR spectroscopy. − [c] Measured in acetone solutions; concentrations are rounded to the nearest tenth. − [f] ee values for deuterated optically active compounds were calculated assuming that substitution of hydrogen by deuterium does not change the specific optical rotation; ee values of deuterated **21a** refer to starting materials. − [g] Tol. = Toluene. − [h] Calculated assuming that the specific rotation of optically pure stannane (−)-**21c** is −40.8. − [i] Determined by derivatisation of alcohols obtained by reduction with DIBAH with (*S*)-(+)-Mosher chloride (see Scheme 9).

moyloxy-substituted carbanion[16], which retains its stereochemistry in the presence of TMEDA in diethyl ether and pentane, but not in THF.

To study the chemical stability of carbanion **19**, a THF solution of it in racemic form was allowed to warm up slowly from −78 to −20 °C. Under these conditions carbanion **19** rearranges in 81% yield to hydroxy ketone (±)-**24**. When the carbanion was generated from optically active ester (+)-**16** in toluene/20% diethyl ether and the reaction mixture was allowed to warm to −20 °C also racemic hydroxy ketone (ee <5%) **24** resulted. The recovered starting material was fully racemic. Hydroxy ketone **24** is formed by intramolecular rearrangement (ester−hydroxy ketone rearrangement) of carbanion **19** and not via benzoylation of α-oxy-α-methylbenzyllithium **19** followed by ester cleavage by excess *s*BuLi on the following evidence. Since formation of carbanion **19** is complete in less than 30 min there is no starting material **16** left to acylate dipole-stabilized **19**, and the carbonyl function of ester **16** is shielded against addition of nucleophiles. Furthermore, Beak et al.[10] have proposed such a mechanism for the rearrangement of the carbanion derived from allyl 2,4,6-triisopropylbenzoate. This isomerisation might be developed into a method for the synthesis of sterically crowded α-hydroxy ketones and vicinal diols. A structure similar to tetrahedral intermediate **22** has been proposed for the rearrangement of deprotonated (acyloxy)acetates, induced by collisional activation mass spectroscopy, to (acyl)hydroxyacetates in the gas phase, besides other reactions[17].

Dipole-stabilized carbanion **19** was treated with electrophiles (**20b**−**20e**) such as chlorotrimethylsilane, chlorotrimethylstannane, methyl chloroformate and dimethyl carbonate to afford optically active derivatives **21b**−**21d** of unknown configuration and optical purity (entries 11−14). Use of a chiral shift reagent [(+)-Eu(hfc)$_3$] and ^{1}H-NMR spectroscopy for determining the ee value of the products was not successful, probably because the lanthanoid reagent cannot form a complex with the shielded ester group.

When these experiments were already finished, it was found that the deprotonation of ester **16** can be carried out within 10 min with *s*BuLi without TMEDA in toluene containing 20% of diethyl ether in 94% yield (entries 15 and 16). Surprisingly, the enantiomeric excess was 95% and it did not change when the reaction time was increased to 60 min (entry 17). α-Oxy-α-methylbenzyl anion **19** is apparently configurationally stable under these conditions. When it was treated with electrophiles **20c**−**20e**, the specific optical rotations of products **21c** and **21d** were higher than when the carbanion was formed in hexane with *s*BuLi/TMEDA. For comparison, racemic carbanion **19** was allowed to react with chlorotrimethylstannane and methyl chloroformate (entries 21 and 22).

Crystallisation of tin compound (−)-**21c** with $[\alpha]_D^{20}$ = −40.8 did not increase the specific rotation ($[\alpha]_D^{20}$ = −40.8). Assuming that the material obtained is enantiomerically pure, the product of entry 12 has an ee value of 22% and that of entry 18 ≥ 98%. The stannylation of ester **16** occurs with at least 98% retention or inversion of configuration.

Stannane (−)-**21c** (≥98% ee) was transformed with an excess of *s*BuLi by tin−lithium exchange within 10 min to carbanion **19** which was treated with AcOD to afford ester (*S*)-(−)-**21a** with an ee value of ≥98% and starting material (19%) (Scheme 8). The ester used for the preparation of stannane (−)-**21c** had (*R*) configuration. Consequently, one of the steps on the way to (*S*)-**21a** must occur with inversion of configuration, indicating that the carbanion is configurationally stable and that stannylation proceeds uniformly. There are four steps, deprotonation, stannylation, tin−lithium exchange, and deuteration on the way from ester (*R*)-**16** to product (*S*)-**21a**. Deprotonation and deuteration occur, as has been shown before, with overall retention of configuration to the extent of 95%. As the starting stannane has an ee value of ≥98% and the protonation of carbanion **19** proceeds with at least 98% retention of configuration, the tin is exchanged for lithium with the same stereoselectivity. If the concept that tin−lithium exchange proceeds with retention of stereochemistry[18], though not rigorously proven, holds for this case as well, the stannylation has to result by inversion of configuration. The stereochemistry of silane **21b** is not known yet. As silylation and stannylation of ester (*S*)-(−)-**16** afford dextrorotatory products, it might be that they also have the same configuration. Experiments are under way to determine the configuration of a stannane derived from an optically active ester **16** and a homochiral halogenostannane.

Scheme 8

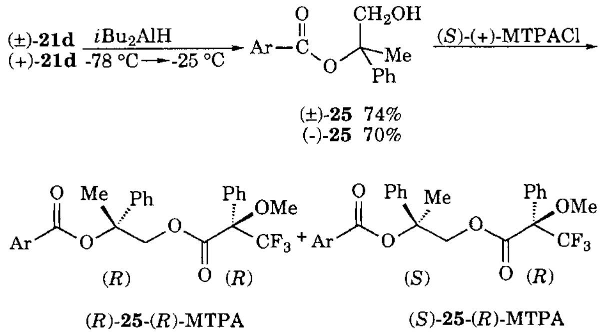
$$(-)\text{-}\mathbf{21c} \xrightarrow[\text{2) AcOD}]{\text{1) }s\text{BuLi/-78 °C, toluene/20\% Et}_2\text{O}} (-)\text{-}\mathbf{21a}$$

$[\alpha]_D^{20} = -40.8$ 65% $[\alpha]_D^{20} = -20.0$

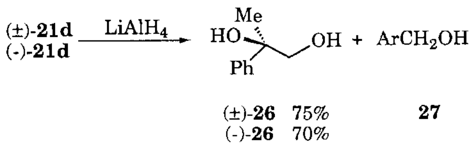
ee ≥98% ee ≥98%

The absolute configuration and enantiomeric excess of **21d** were determined by chemical means. The reactivity of the two ester functions is different enough to allow a regioselective manipulation. Diester **21d** in racemic and optically active form was reduced with *i*Bu$_2$AlH in toluene to hydroxymethyl benzoate **25** (Scheme 9). Esterification of alcohol (±)-**25** with Mosher's acid chloride [(*S*)-(+)-MTPACl][19] in pyridine furnished an inseparable mixture of the two diastereomeric Mosher esters (*R*)-MTPA-(*R*)-**25** and (*R*)-MTPA-(*S*)-**25**. It shows in the ^{1}H-NMR spectrum for the methylene groups two overlapping AB systems (δ = 4.70 and 4.72) and singlets (δ = 2.01 and 2.05) for the methyl groups of the diol portions of equal intensity. The ratio changed to 1:26 and 1:8, when two different samples of optically active ester (+)-**21d** (from entries 19 and 20 in Table 1) were reduced and derivatised, corresponding to enantiomeric excesses of 93% and 78%, respectively. The absolute configuration of diester (−)-**21d** (not given in Table 1) was correlated with known diol (+)-**26** obtained by reduction of (*S*)-(+)-atrolactic acid[20]. Diesters (±)-**21d** and (−)-**21d** were reduced in diethyl ether with a large excess of LiAlH$_4$ to give 2,4,6-triisopropylphenylmethanol **27** and racemic and levorotatory diol **26**, respectively (Scheme 10).

Scheme 9



Scheme 10



Therefore, the asymmetrically substituted carbon of diol (−)-**26** and consequently diester (−)-**21d** has (*R*) configuration. As diester (−)-**21d** was prepared from (*R*)-(+)-**16**, the acylation of the corresponding carbanion (*R*)-**19** with methyl chloroformate or dimethyl carbonate must occur with retention of configuration.

2,4,6-Triisopropylbenzoyloxy-substituted α-methylbenzyllithium **19** as dipole-stabilized carbanion is generated in high yield by deprotonation of the corresponding ester **16** with *s*BuLi within 10 min in toluene/20% diethyl ether at −78 °C and is virtually configurationally stable. It racemises partly in the presence of TMEDA in hexane and completely in THF. It is deuterated and acylated with retention of configuration. The stereochemical outcome of silylation and stannylation remains to be rigorously proven. These results demonstrate that α-methylbenzyllithium with a 2,4,6-triisopropylbenzoyloxy instead of a carbamoyloxy substituent (**1a**; R^1 = Me, R^2 = Ph, R = *i*-Pr) is configurationally less stable and behaves stereochemically different. The latter reacts with a variety of electrophiles with either retention or inversion of configuration, depending on the electrophile used as reported by Hoppe et al.[16]. Carbanion **1a** is acylated with methyl chloroformate and dimethyl carbonate to give products with inversion and retention of configuration, respectively, in contrast to results obtained for carbanion **19**. They also found that α-methylbenzyllithium **1a** is stannylated by treatment with chlorotrimethylstannane with inversion of configuration, assuming that tin−lithium exchange is effected with retention of stereochemistry. It is protonated with methanol with retention and surprisingly with acetic acid and triphenylmethane with inversion of configuration. We have repeated these protonation experiments of **1a** with acetic acid and methanol and found that they afford products with retention of configuration in both cases[21]. The cases reported here support theoretical calculations by Schleyer et al.[22] and experimental results by

Hoppe et al. that electrophilic substitutions (S_E2 mechanism) can cause either inversion or retention of configuration. The subtleties determining the stereochemistry are still largely unknown.

Conclusions

α-Pivaloyloxy- and α-2,4,6-triisopropylbenzoyloxy-substituted α-methylbenzyllithium compounds are dipole-stabilized carbanions. Their difference in chemical reactivity is a consequence of the different accessibility of the carbonyl functions. The former compounds are at least partly configurationally stable for the short period of their lifetime before they are acylated by starting material. The 2,4,6-triisopropylbenzoyloxy-substituted carbanion with a much more shielded C=O is practically configurationally stable in toluene/20% diethyl ether without TMEDA and reacts with externally added electrophiles. When it is warmed up, it rearranges to the isomeric racemic hydroxy ketone (**24**), reminiscent of the phosphate–phosphonate rearrangement. Tertiary benzylic anions, produced by Haller–Bauer cleavage, are usually protonated with retention of configuration[23], whereas α-oxy-substituted benzyl anions, being involved in the Brook and reverse Brook rearrangement, react with inversion of configuration[24]. Phosphoryloxy-substituted benzyl anions involved in the phosphate–phosphonate rearrangement react with retention of configuration[6,9]. The mechanism for the inversion of configuration of acyloxy-substituted carbanions remains to be elucidated. It has been proposed on the basis of NMR-spectroscopic investigations that the rate-determining step for the inversion of configuration of α-heteroatom-substituted carbanions is the rotation around the carbon–heteroatom bond[25]. Whether this mechanism is also operative here is unknown.

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Experimental

TLC: Merck precoated TLC plates (0.25 mm), silica gel 60, F_{254}; detection: UV and/or spraying with a 2% solution of $Ce^{IV}SO_4 \cdot 4\,H_2O$ in 2 N H_2SO_4 and heating on a hot plate. – Flash chromatography: Merck silica gel 60, 0.040–0.063 mm; eluents: Petroleum ether (PE, boiling point 60–95 °C), ethyl acetate (EA). – IR: Perkin-Elmer FT 1600 IR-Spectrometer, (NaCl: film; Si[26]: a solution of the sample in Uvasol $CHCl_3$ was applied to a Si plate and the solvent was allowed to evaporate). – ^1H NMR: Bruker spectrometers AC 250F or AM 400 WB; TMS as internal standard. – Optical rotation: Perkin-Elmer polarimeter 141 (1 dm cell). – Melting points were measured with a Reichert Thermovar instrument and are uncorrected. – Reactions were carried out in dry solvents. THF was distilled from potassium and diethyl ether from lithium aluminum hydride. Hexane was dried over molecular sieve (4 Å). – (*S*)-(+)-α-Methoxy-α-(trifluoromethyl)phenylacetyl chloride [JPS Chimie; $[\alpha]_D^{20} = +136.5$ (c = 5.2, CCl_4), ee ≥99.5%)] was used for derivatization of alcohols. – Optically active 1-phenylethanols were prepared by enzymatic resolution of racemic 1-phenylethyl acetate[27]. When the reaction was stopped at a conversion of about 50% as determined from the base added, the alcohols had an enantiomeric excess of 93% [determined by polarimetry; $[\alpha]_D^{20} = -11.04$ (0.25 dm, neat)[28] for 100% ee]. When the enzymatic hydrolysis was stopped at 42% conversion and the optically enriched ester was treated prior to chemical hydrolysis again with lipase until consumption of the base was negligible to keep the pH constant, alcohols with ee values ≥97% were obtained.

1-Phenylethyl 2,2-Dimethylpropionate [(±)-**7a**, and (*S*)-(–)-**7a**]: A solution of pivaloyl chloride (**5a**) (3.62 g, 30 mmol) and chiral or racemic 1-phenylethanol [(±)-**6**] (2.44 g, 20 mmol) in dry pyridine (30 ml) was refluxed until completion of reaction (TLC) (ca. 12 h). The mixture was hydrolysed with ice/water, extracted with diethyl ether and the extract was washed with 2 N hydrochloric acid, a saturated aq. solution of $NaHCO_3$, water and dried with $MgSO_4$. Removal of volatile components in vacuo gave a residue which was purified by flash chromatography [PE/diisopropyl ether (30:1); R_f = 0.48] and bulb-to-bulb distillation (b.p. 115 °C/4 Torr) to afford ester (±)-**7a** (3.71 g, 90%). Alcohol (*S*)-(–)-**6** (ee = 93%) was transformed analogously into ester (*S*)-(–)-**7a** in 92% yield, $[\alpha]_D^{20} = -69.8$ (c = 2.29, acetone). – IR (NaCl): $\tilde{\nu}$ = 3066 cm^{-1}, 3034, 2978, 2933, 2873, 1730, 1496, 1480, 1455, 1396, 1368, 996. – ^1H NMR (400 MHz, $CDCl_3$): δ = 1.21 [s, 9H, $C(CH_3)_3$], 1.51 (d, J = 6.4 Hz, 3H, $OCHCH_3$), 5.85 (q, J = 6.4 Hz, 1H, $OCHCH_3$), 7.30 (m, 5H, Ph). – $C_{13}H_{18}O_2$ (206.29): calcd. C 75.69, H 8.80; found C 76.03, H 9.46.

(1S,4R,1'S)-1-Phenylethyl Camphanoate (**7b**): A solution of (*S*)-(–)-camphanoyl chloride [(*S*)-(–)-**5b**] (2.25 g, 10.5 mmol) and (*S*)-(–)-1-phenylethanol [(*S*)-(–)-**6**] (ee = 93%) (0.98 g, 8 mmol) in dry pyridine (30 ml) was refluxed until completion of reaction (TLC) (ca. 24 h). The mixture was hydrolysed with ice/water, extracted with diethyl ether and the extract was washed with 2 N hydrochloric acid, a saturated aq. solution of $NaHCO_3$ and dried with $MgSO_4$. The filtrate was concentrated in vacuo and the residue was purified by flash chromatography [PE/EA (3:1); R_f = 0.48] to yield ester (–)-**7b** (2.50 g, 87%) as white crystals, m.p. 86 °C (PE/Et_2O), $[\alpha]_D^{20} = -35.7$ (c = 2.07, acetone). – IR (Si): $\tilde{\nu}$ = 2975 cm^{-1}, 1782, 1734, 1472, 1450, 1365, 1347, 1330, 1304, 1268, 1171, 1100, 1058, 1021. – ^1H NMR (250 MHz, $CDCl_3$): δ = 0.93 (s, 3H, CH_3), 1.02 (s, 3H, CH_3), 1.11 (s, 3H, CH_3), 1.60 (d, J = 6.6 Hz, 3H, $OCHPhCH_3$), 1.70 (m, 1H), 1.97 (m, 2H), 2.42 (m, 1H), 6.03 (q, J = 6.6 Hz, 1H, $OCHPhCH_3$), 7.37 (m, 5H, Ph). – $C_{18}H_{22}O_4$ (302.37): calcd. C 71.49, H 7.34; found C 71.52, H 7.57.

Deprotonation of Esters (±)-**7a** *and* (*S*)-(–)-**7a**: *n*BuLi in hexane (15%, 1.9 ml, 3 mmol) was added to a solution of 2,2,6,6-tetramethylpiperidine (0.42 g, 0.5 ml, 3 mmol) in freshly distilled dry THF (10 ml) under argon at 0 °C. After stirring for 5 min the solution was cooled to –78 °C and ester (±)-**7a** (0.31 g, 1.5 mmol) was added by means of a syringe. The solution was stirred for 2 h before quenching with AcOD (2 ml). The solution was warmed to room temperature, concentrated in vacuo and the residue was taken up in CH_2Cl_2, washed with 2 N hydrochloric acid, a saturated aq. solution of $NaHCO_3$ and water and dried with $MgSO_4$. The solvent was evaporated and the residue was purified by flash chromatography [PE/EA (4:1); R_f = 0.83] to yield keto ester (±)-**10** (0.20 g, 92%). Optically active ester (*S*)-(–)-**7a** was treated in the same way to afford keto ester (+)-**10** in 57% yield, $[\alpha]_D^{20} = +12.0$ (c = 1.25, acetone). – IR (NaCl): $\tilde{\nu}$ = 2971 cm^{-1}, 1731, 1601, 1583, 1479, 1396, 1367, 1284, 1227, 1156, 1071, 1030, 995. – ^1H NMR (250 MHz, $CDCl_3$): δ = 1.00 [s, 9H, $(CH_3)_3CCO$], 1.35 [s, 9H, $(CH_3)_3CCO_2$], 1.75 (s, 3H, $OCCH_3Ph$), 7.40 (m, 5H, Ph). – $C_{18}H_{26}O_3$ (290.40): calcd. C 74.45, H 9.02; found C 74.57, H 9.57.

Saponification of Keto Esters (±)-**10** *and* (+)-**10**: Water (0.04 g, 2.3 mmol) was added to a mixture of *t*BuOK (0.90 g, 9.0 mmol) and diethyl ether (25 ml) at 0 °C. After stirring for 5 min keto ester

(±)-**10** (0.3 g, 1.0 mmol) was added. The mixture was warmed to room temp. and after stirring for 4 h water was added. The organic layer was washed with 2 N hydrochloric acid, a saturated aq. solution of $NaHCO_3$ and water and dried with $MgSO_4$. The product was purified by flash chromatography [PE/Et_2O (10:1); $R_f = 0.16$] to yield hydroxy ketone (±)-**11** (0.13 g, 63%). Optically active keto ester (+)-**10** was saponified by the same procedure to afford hydroxy ketone (+)-**11** in 63% yield, $[\alpha]_D^{20} = +15.8$ (c = 2.69, acetone). – IR (NaCl): $\tilde{\nu}$ = 3490 cm^{-1}, 2960, 2931, 1690, 1482, 1461, 1447, 1365, 1287, 1223, 1149, 1120, 1068, 1042, 1029. – ^1H NMR (250 MHz, $CDCl_3$): δ = 1.05 [s, 9H, $(CH_3)_3CCO$] 1.80 (s, 3H, CCH_3Ph), 4.40 (s, 1H, OH), 7.35 (m, 5H, Ph). – $C_{13}H_{18}O_2$ (206.29): calcd. C 75.69, H 8.80; found C 75.51, H 8.30.

Attempted Deprotonation of Ester (–)-**7b**: *t*BuLi in pentane (1.7 M, 1.8 ml, 3.0 mmol) was added to a solution of (–)-**7b** (0.30 g, 1.0 mmol) in freshly distilled THF at –78 °C under argon. After stirring for 30 min a solution of D_2O (5 mmol, 0.1 ml) in dry THF (1 ml) was added. The mixture was allowed to warm to room temp. and THF was removed. The residue was taken up in CH_2Cl_2, the solution was washed with 2 N hydrochloric acid, a saturated aq. solution of $NaHCO_3$ and water and dried with $MgSO_4$. The crude product was purified by flash chromatography [PE/EA (3:1); R_f = 0.60] to give ketone (–)-**12a** (0.07 g, 30%), $[\alpha]_D^{20} = -31.6$ (c = 2.27, acetone). – IR (NaCl): $\tilde{\nu}$ = 2968 cm^{-1}, 2934, 2877, 1794, 1703, 1458, 1396, 1377, 1332, 1310, 1260, 1222, 1165, 1125, 1086, 1056, 1024. – ^1H NMR (250 MHz, $CDCl_3$): δ = 0.88 (s, 3H, CH_3), 1.09 (s, 3H, CH_3), 1.13 (s, 3H, CH_3), 1.25 [s, 9H, $C(CH_3)_3$], 1.68 (m, 1H), 1.95 (m, 2H), 2.29 (m, 1H). – $C_{14}H_{22}O_3$ (238.33): calcd. C 70.56, H 9.30; found C 70.79, H 9.27.

1-Phenylethyl 2,4,6-Triisopropylbenzoate [(±)-**16**, (*R*)-(+)-**16** and (*S*)-(–)-**16**]: Diethyl azodicarboxylate (**15**) (3.48 g, 24 mmol) was slowly added to a cooled (ice/water) solution of (*S*)-(–)-1-phenylethanol [(*S*)-(–)-**6**] (ee ≥97%) (2.44 g, 20 mmol), triphenylphosphane (**14**) (6.29 g, 24 mmol) and 2,4,6-triisopropylbenzoic acid (**13**) (5.96 g, 24 mmol) in dry toluene (40 ml) under argon. The mixture was stirred for 1 h at 0 °C and 3 h at room temp., and controlled by TLC [CH_2Cl_2/PE (2:3)]. Volatile components were removed in vacuo and the residue was triturated with diethyl ether and allowed to stand for 1 h at 4 °C (to remove Ph_3PO and hydrazo ester). The filtrate was concentrated and the residue was purified by flash chromatography [CH_2Cl_2/PE (3:2); R_f = 0.30] and then subjected to bulb-to-bulb distillation (145 °C/0.02 Torr) to afford ester (*R*)-(+)-**16** as viscous, colourless oil (5.64 g, 80%) which slowly crystallised (m.p. 45–55 °C), $[\alpha]_D^{20} = +19.51$ (c = 2.06, acetone). Esters (*S*)-(–)-**16** (ee ≥97%), m.p. 45–55 °C, $[\alpha]_D^{20} = -19.76$ (c = 2.47, acetone), and (±)-**16**, m.p. 33 °C, were prepared by the same procedure in yields of 73% and 43%, respectively. – IR (NaCl): $\tilde{\nu}$ = 2962 cm^{-1}, 2930, 2870, 1725, 1460, 1250, 1060. – ^1H NMR (400 MHz, $CDCl_3$): δ = 1.08 [d, J = 6.9 Hz, 6H, $CH(CH_3)_2$], 1.11 [d, J = 6.9 Hz, 6H, $CH(CH_3)_2$], 1.16 [d, J = 6.9 Hz, 6H, $CH(CH_3)_2$], 1.58 (d, J = 6.9 Hz, 3H, $OCHPhCH_3$), 2.68 (sept, J = 6.9 Hz, 2H, $CH(CH_3)_2$), 2.80 [sept, J = 6.9 Hz, 1H, $CH(CH_3)_2$], 6.11 (q, J = 6.9 Hz, 1H, $CHPhCH_3$), 6.91 (s, 2H, 3-H and 5-H of Ar), 7.30 (m, 5H, Ph). – $C_{24}H_{32}O_2$ (352.52): calcd. C 81.76, H 9.16; found C 81.47, H 9.72.

General Procedure for the Deprotonation of Ester **16**: A solution of *s*BuLi in cyclohexane/hexane (92:8) (12%, 1.5 ml, 2 mmol) was added to a solution of ester **16** (0.35 g, 1 mmol) in the solvent given in Table 1 (10 ml of hexane, THF or toluene or 10 ml of toluene with 1 or 2 ml of diethyl ether) under argon at –78 °C. After stirring for the specified time the electrophile **20** (5 mmol of **20a** or 4 mmol of **20b**–**20e** in 1 ml of solvent as used for the reaction) was added. The cooling bath was removed when the colour had disappeared and the mixture was allowed to warm to room temp. Volatile components were removed in vacuo. The residue was taken up in CH_2Cl_2 and the solution was washed with 2 N hydrochloric acid, a saturated aq. solution of $NaHCO_3$, water and dried with $MgSO_4$ and then concentrated in vacuo. The residue was purified by flash chromatography [PE/Et_2O (20:1)] to yield product **21** (Table 1).

1-Phenyl-1-[D]ethyl 2,4,6-Triisopropylbenzoate (**21a**): R_f = 0.46. – IR (NaCl): $\tilde{\nu}$ = 2962 cm^{-1}, 2870, 1725, 1462, 1363, 1253, 1139, 1094, 1085, 1073. – ^1H NMR (250 MHz, $CDCl_3$): δ = 1.15 [d, J = 6.9 Hz, 6H, $CH(CH_3)_2$], 1.19 [d, J = 6.9 Hz, 6H, $CH(CH_3)_2$], 1.23 [d, J = 6.9 Hz, 6H, $CH(CH_3)_2$], 1.65 (s, 3H, $CDCH_3$), 2.76 [sept, J = 6.9 Hz, 2H, $CH(CH_3)_2$], 2.87 [sept, J = 6.9 Hz, 1H, $CH(CH_3)_2$], 6.90 (s, 2H, 3-H and 5-H of Ar), 7.30 (m, 5H, Ph).

1-Phenyl-1-(trimethylsilyl)ethyl 2,4,6-Triisopropylbenzoate (**21b**): The product was purified by flash chromatography [PE/toluene (5:1)] to give an oil, R_f = 0.19. $[\alpha]_D^{20} = +19.5$ (c = 1.20, acetone). – IR (NaCl): $\tilde{\nu}$ = 2962 cm^{-1}, 2929, 2870, 1727, 1607, 1461, 1446, 1363, 1285, 1249, 1133, 1102, 1061, 1050, 1033. – ^1H NMR (250 MHz, $CDCl_3$): δ = 0.05 [s, 9H, $Si(CH_3)_3$], 1.26 [d, J = 6.9 Hz, 12H, $CH(CH_3)_2$], 1.28 [d, J = 6.9 Hz, 6H, $CH(CH_3)_2$], 2.10 (s, 3H, $OCCH_3$), 2.90 [sept, J = 6.9 Hz, 1H, $CH(CH_3)_2$], 3.09 [sept, J = 6.9 Hz, 2H, $CH(CH_3)_2$], 7.00 (s, 2H, 3-H and 5-H of Ar), 7.25 (m, 5H, Ph). – $C_{27}H_{38}O_2Si$ (422.68): calcd. C 76.72, H 9.06; found C 76.30, H 9.46.

1-Phenyl-1-(trimethylstannyl)ethyl 2,4,6-Triisopropylbenzoate [(±)-**21c**, (–)-**21c**, (+)-**21c**]: R_f = 0.58, m.p. of (±)-**21c** 50 °C (ethanol); chromatographically homogeneous (–)-**21c** {$[\alpha]_D^{20} = -40.8$ (c = 5.19, acetone) entry 18 in Table 1} was crystallised from ethanol to give a material with m.p. 65 °C, $[\alpha]_D^{20} = -40.8$ (c = 2.40, acetone). It was assumed to be enantiomerically pure. – IR (Si) of (–)-**21c**: $\tilde{\nu}$ = 2962 cm^{-1}, 2931, 2870, 1725, 1606, 1469, 1430, 1383, 1363, 1283, 1251, 1138, 1103, 1075, 1029. – ^1H NMR (250 MHz, $CDCl_3$): δ = 0.05 [s, 9H, $Sn(CH_3)_3$] with two satellite doublets (J = 50.3 Hz, 52.5 Hz) for $^{117/119}Sn$ isotopomers, 1.23 [d, J = 6.9 Hz, 6H, $CH(CH_3)_2$], 1.25 [d, J = 6.9 Hz, 6H, $CH(CH_3)_2$], 1.31 [d, J = 6.9 Hz, 6H, $CH(CH_3)_2$], 1.90 (s, 3H, $OCCH_3$), 2.87 [sept, J = 6.9 Hz, 1H, $CH(CH_3)_2$], 3.03 [sept, J = 6.9 Hz, 2H, $CH(CH_3)_2$], 6.90 (s, 2H, 3-H and 5-H of Ar), 7.15 (m, 5H, Ph). – $C_{27}H_{38}O_2Sn$ (513.29): calcd. C 63.18, H 7.46; found C 63.06, H 8.08.

Methyl 2-Phenyl-2-(2,4,6-triisopropylbenzoyloxy)propionate (**21d**): R_f = 0.13. – IR (Si) (±)-**21d**: $\tilde{\nu}$ = 2962 cm^{-1}, 1750, 1734, 1460, 1449, 1372, 1260, 1228, 1188, 1124, 1103, 1072. – ^1H NMR (250 MHz, $CDCl_3$): δ = 1.25 [d, J = 6.9 Hz, 6H, $CH(CH_3)_2$], 1.27 [d, J = 6.9 Hz, 6H, $CH(CH_3)_2$], 1.28 [d, J = 6.9 Hz, 6H, $CH(CH_3)_2$], 2.10 (s, 3H, $OCCH_3$), 2.90 [sept, J = 6.9 Hz, 1H, $CH(CH_3)_2$], 3.10 [sept, J = 6.9 Hz, 2H, $CH(CH_3)_2$], 3.75 (s, 3H, $COOCH_3$), 7.05 (s, 2H, 3-H and 5-H of Ar), 7.20–7.60 (m, 5H, Ph). – $C_{26}H_{34}O_4$ (410.55): calcd. C 76.05, H 8.35; found C 75.56, H 8.68.

Procedure for Lithiodestannylation of (–)-**21c**: A solution of *s*BuLi in cyclohexane/hexane (92:8) (12%, 0.5 ml, 0.7 mmol) was added dropwise to a solution of (–)-**21c** (0.07 g, 0.14 mmol, ee ≥98%) in toluene/20% diethyl ether at –78 °C under argon. After stirring for 10 min deuterated acetic acid (1 ml) was added and the mixture was warmed to room temp. Volatile components were removed in vacuo and the residue was taken up in CH_2Cl_2. The solution was washed with 2 N hydrochloric acid, a saturated aq. solution of $NaHCO_3$ and water and dried with $MgSO_4$. The solution was concentrated and the residue was purified by flash chromatography [PE/Et_2O (20:1)] to give product (–)-**21a** (0.03 g, 65%; R_f = 0.38; ee ≥98%) besides the unreacted ester (–)-**21c** (0.01 g, 19%; R_f = 0.74; ee ≥98%).

2-Hydroxy-2-phenyl-1-(2,4,6-triisopropylphenyl)-1-propanone [(±)-**24** and (+)-**24**]: A solution of *s*BuLi in cyclohexane/hexane (92:8) (12%, 1.1 ml, 1.5 mmol) was added dropwise to a solution of ester (±)-**16** (0.352 g, 1 mmol) in freshly distilled THF under argon at −78 °C. The mixture was allowed to warm to −20 °C and was then treated with THF/water. Volatiles were removed in vacuo. The residue was taken up in CH_2Cl_2, and the solution was washed with 2 N hydrochloric acid, a saturated aq. solution of $NaHCO_3$, water, dried with $MgSO_4$ and concentrated in vacuo. The residue was purified by flash chromatography [PE/Et_2O (20:1); $R_f = 0.25$] to yield (±)-**24** (0.22 g, 63%), m.p. 96 °C (PE). The optical rotation of enantiomerically pure hydroxy ketone **24** was determined by resolution by MPLC on triacetylcellulose as $[\alpha]_D^{20} = -18.7$ ($c = 1.85$, EtOH)[15,29]. An analogous reaction was carried out with (*R*)-(+)-**16** in toluene/20% diethyl ether to yield hydroxy ketone (+)-**24** (0.05 g, 14%), $[\alpha]_D^{20} = +0.85$ ($c = 1.18$, acetone). The recovered starting material (0.02 g, 5%) was racemic. – IR (Si): $\tilde{\nu} = 3467$ cm^{-1}, 2963, 2932, 2869, 1697, 1605, 1569, 1492, 1460, 1446, 1384, 1363, 1217, 1151, 1099, 1070, 1054, 1028. – ^1H NMR (400 MHz, $CDCl_3$): $\delta = 0.90$ [d, $J = 6.9$ Hz, 6H, $CH(CH_3)_2$], 1.05 [d, $J = 6.9$ Hz, 6H, $CH(CH_3)_2$], 1.25 [d, $J = 6.9$ Hz, 6H, $CH(CH_3)_2$], 1.85 [s, 3H, $C(OH)CH_3$], 2.05 [sept, $J = 6.9$ Hz, 1H, $CH(CH_3)_2$], 2.40 [sept, $J = 6.9$ Hz, 1H, $CH(CH_3)_2$], 2.90 [sept, $J = 6.9$ Hz, 1H, $CH(CH_3)_2$], 3.20 (s, 1H, OH), 6.95 (s, 2H, 3-H and 5-H of Ar), 7.25 (m, 3H, Ph), 7.50 (m, 2H, Ph). – $C_{24}H_{32}O_2$ (352.52): calcd. C 81.76, H 9.16; found C 81.33, H 9.42.

2-Phenyl-2-(2,4,6-triisopropylbenzoyloxy)-1-propanol [(±)-**25** or (−)-**25**]: A solution of DIBAH in hexane (1 M, 1 ml, 1 mmol) was added by means of a syringe to a solution of diester (+)-**21d** (0.08 g, 0.2 mmol) in toluene at −78 °C under argon. The mixture was allowed to warm slowly to −25 °C (in the cooling bath) and then treated with water. Volatile components were removed in vacuo. The residue was taken up in CH_2Cl_2 and the solution was washed with 2 N hydrochloric acid, a saturated aq. solution of $NaHCO_3$, water, dried with $MgSO_4$ and concentrated in vacuo. The residue was purified by flash chromatography [PE/Et_2O (5:1); $R_f = 0.17$] to yield (−)-**25** (0.06 g, 74%), $[\alpha]_D^{20} = -20.8$ ($c = 1.98$, acetone). By using racemic diester (±)-**21d**, racemic alcohol (±)-**25** was isolated in 70% yield. – IR (Si) (−)-**25**: $\tilde{\nu} = 3468$ cm^{-1}, 2959, 2928, 2870, 1728, 1606, 1496, 1461, 1448, 1430, 1383, 1363, 1285, 1252, 1186, 1154, 1138, 1103, 1066, 1028. – ^1H NMR (250 MHz, $CDCl_3$): $\delta = 1.25$ [2 × d overlapping, $J = 6.9$ Hz, 12H, $CH(CH_3)_2$], 1.26 [d, $J = 6.9$ Hz, 6H, $CH(CH_3)_2$], 2.10 (s, 3H, $OCCH_3$), 2.95 [3 × sept. overlapping, $J = 6.9$ Hz, 3H, $CH(CH_3)_2$], 3.92 (AB system, $J = 12.4$ Hz, 2H, CH_2OH), 7.05 (s, 2H, 3-H and 5-H of Ar), 7.40 (m, 5H, Ph). – $C_{25}H_{34}O_3$ (382.54): calcd. C 78.49, H 8.96; found C 78.56, H 9.15.

Synthesis of Mosher's Ester of Alcohols (±)-**25** *and* (−)-**25**: A solution of (±)-**24** (0.02 g, 0.05 mmol), (*S*)-(+)-MTPA-Cl (0.06 g, 0.24 mmol) and a catalytic amount of 4-(dimethylamino)pyridine in dry pyridine (1 ml) was stirred for 48 h at room temp. under argon. Pyridine was removed in vacuo. The residue was taken up in CH_2Cl_2 and the solution was washed with 2 N hydrochloric acid, a saturated aq. solution of $NaHCO_3$, water, dried with $MgSO_4$ and concentrated in vacuo. The residue was purified by flash chromatography [PE/EA (9:1); $R_f = 0.47$] to yield a mixture of diastereomeric esters (*R*)-MTPA-(*R*)-**25** and (*R*)-MTPA-(*S*)-**25** (0.02 g, 75%). The diastereomeric excess of **25** can be determined by ^1H-NMR spectroscopy. The assignment of signals to the individual components of the diastereomeric mixture was possible by a comparison of the ^1H-NMR spectra of Mosher's esters derived from racemic and enantiomerically enriched alcohols **25**.

(*R*)-MTPA-(*S*)-**25**: ^1H NMR (400 MHz, $CDCl_3$): $\delta = 1.09$, 1.18, 1.19 [3 × d, $J = 6.9$ Hz, 18H, $CH(CH_3)_2$], 2.05 (s, 3H, CH_3), 2.90 [3 × sept overlapping, $J = 6.9$ Hz, 3H, $CH(CH_3)_2$], 3.25 (s, 3H, OCH_3), 4.72 (AB system, $J = 11.3$ Hz, 2H, CCH_2O), 6.91 (s, 2H, 3-H and 5-H of Ar), 7.30 (m, 10H, 2 × Ph).

(*R*)-MTPA-(*R*)-**25**: ^1H NMR (400 MHz, $CDCl_3$): $\delta = 1.04$, 1.12, 1.16 [3 × d, $J = 6.9$ Hz, 18H, $CH(CH_3)_2$], 2.01 (s, 3H, CH_3), 2.90 [3 × sept overlapping, $J = 6.9$ Hz, 3H, $CH(CH_3)_2$], 3.27 (s, 3H, OCH_3), 4.70 (AB system, $J = 11.3$ Hz, 2H, CCH_2O), 6.91 (s, 2H, 3-H and 5-H of Ar), 7.30 (m, 10H, 2 × Ph).

2-Phenyl-1,2-propanediol [(±)-**26** and (−)-**26**]: A solution of (±)-**21d** (0.14 g, 0.4 mmol) in freshly distilled diethyl ether (5 ml) was added to a suspension of $LiAlH_4$ (0.08 g, 2 mmol) in freshly distilled dry diethyl ether (5 ml). The reaction mixture was refluxed for 5 h, treated with a small amount of water, mixed with a 10% solution of NaOH in water and extracted continuously with diethyl ether for 5 h. The organic phase was washed with water, dried with $MgSO_4$ and concentrated in vacuo. The residue was purified by flash chromatography [PE/EA (1:1); $R_f = 0.32$] to afford diol (±)-**26** (0.057 g, 75%) as an oil. Diester (*R*)-(−)-**21d** {$[\alpha]_D^{20} = -1.04$ ($c = 7.13$, acetone)} was reduced similarly to give diol (−)-**26** (70%), $[\alpha]_D^{20} = -6.6$ ($c = 1.80$, Et_2O) [ref.[20] $[\alpha]_D^{20} = +8.94$ ($c = 6.76$, Et_2O)]. – IR (NaCl): $\tilde{\nu} = 3386$ cm^{-1}, 3088, 3060, 3028, 2961, 2931, 2873, 1723, 1644, 1446, 1378, 1288, 1128, 1071, 1045, 1028. – ^1H NMR (250 MHz, $CDCl_3$): $\delta = 1.50$ (s, 3H, CH_3), 2.25 (s, 1H, OH), 2.85 (s, 1H, OH), 3.67 (AB system, $J = 11.1$ Hz, 2H, CH_2), 7.30 (m, 5H, Ph). – $C_9H_{12}O_2$ (138.17): calcd. C 71.03, H 7.95; found C 71.28, H 8.33.

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[1] V. K. Aggarwal, *Angew. Chem.* **1994**, *106*, 185–187; *Angew. Chem. Int. Ed. Engl.* **1994**, *33*, 175; R. E. Gawley, Q. Zhang, *Tetrahedron* **1994**, *50*, 6077–6088; B. Kaiser, D. Hoppe, *Angew. Chem.* **1995**, *107*, 344–346; *Angew. Chem. Int. Ed. Engl.* **1995**, *34*, 323–325; R. W. Hoffmann, M. Bewersdorf, *Chem. Ber.* **1991**, *124*, 1259–1264; H. Ahlbrecht, J. Harbach, R. W. Hoffmann, T. Ruhland, *Liebigs Ann.* **1995**, 211–216; P. v. Ragué Schleyer, T. Clark, A. J. Kos, G. W. Spitznagel, C. Rohde, D. Arad, K. N. Houk, N. G. Rondan, *J. Am. Chem. Soc.* **1984**, *106*, 6467–6475.

[2] W. C. Still, C. Sreekumar, *J. Am. Chem. Soc.* **1980**, *102*, 1201–1202.

[3] N. G. Rondan, K. N. Houk, P. Beak, W. J. Zajdel, J. Chandrasekhar, P. v. Raguè Schleyer, *J. Org. Chem.* **1981**, *46*, 4108–4110.

[4] D. Hoppe, F. Hintze, P. Tebben, M. Paetow, H. Ahrens, J. Schwerdtfeger, P. Sommerfeld, J. Haller, W. Guarnieri, S. Kolczewski, T. Hense, I. Hoppe, *Pure Appl. Chem.* **1994**, *66*, 1479–1486.

[5] M. Marsch, K. Harms, O. Zschage, D. Hoppe, G. Boche, *Angew. Chem.* **1991**, *103*, 338–339; *Angew. Chem. Int. Ed. Engl.* **1991**, *30*, 321.

[6] F. Hammerschmidt, A. Hanninger, *Chem. Ber.* **1995**, *128*, 823–830.

[7] D. Hoppe, *Angew. Chem.* **1984**, *96*, 930–946; *Angew. Chem. Int. Ed. Engl.* **1984**, *23*, 932.

[8] C. J. Upton, P. Beak, *J. Org. Chem.* **1975**, *40*, 1094–1098.

[9] F. Hammerschmidt, H. Völlenkle, *Liebigs Ann. Chem.* **1986**, 2053–2064.

[10] P. Beak, L. G. Carter, *J. Org. Chem.* **1981**, *46*, 2363–2373.

[11] R. W. Hoffmann, T. Rühl, J. Harbach, *Liebigs Ann. Chem.* **1992**, 725–730; G. Vanermen, S. Toppet, M. Van Beylen, *J. Chem. Soc. Perkin Trans. 2*, **1986**, 707–713.

[12] W. Zarges, M. Marsch, K. Harms, W. Koch, G. Frenking, G. Boche, *Chem. Ber.* **1991**, *124*, 543–549; W. Zarges, M. Marsch, K. Harms, G. Boche, *Chem. Ber.* **1989**, *122*, 2303–2309; W. Zarges, M. Marsch, K. Harms, F. Haller, G. Frenking, G. Boche, *Chem. Ber.* **1991**, *124*, 861–866.

[13] H. B. Bürgi, J. D. Dunitz, J. M. Lehn, G. Wipff, *Tetrahedron* **1974**, *30*, 1563–1572.

[14] P. G. Gassman, W. N. Schenk, *J. Org. Chem.* **1977**, *42*, 918–920.

[15] A. Werner, *Kontake (Merck)*, **1989**, 50–56.

[16] D. Hoppe, A. Carstens, T. Krämer, *Angew. Chem.* **1990**, *102*, 1455–1456; *Angew. Chem. Int. Ed. Engl.* **1990**, *29*, 1424; A. Carstens, D. Hoppe, *Tetrahedron* **1994**, *50*, 6097–6108.

[17] P. C. H. Eichinger, R. N. Hayes, J. H. Bowie, *J. Am. Chem. Soc.* **1991**, *113*, 1949–1953.

[18] D. Hoppe, F. Hintze, P. Tebben, *Angew. Chem.* **1990**, *102*, 1457–1459; *Angew. Chem. Int. Ed. Engl.* **1990**, *29*, 1422; R. J. Linderman, A. Ghannam, *J. Am. Chem. Soc.* **1990**, *112*, 2392–2398; P. C.-M. Chan, J. M. Chong, *Tetrahedron Lett.* **1990**, *31*, 1985–1988.

[19] D. Parker, *Chem. Rev.* **1991**, *91*, 1441–1457.

[20] E. L. Eliel, J. P. Freeman, *J. Am. Chem. Soc.* **1952**, *74*, 923–928.

[21] Prof. D. Hoppe has confirmed our findings (private communication).

[22] E. D. Jemmis, J. Chandrasekhar, P. v. Ragué Schleyer, *J. Am. Chem. Soc.* **1979**, *101*, 527–533.

[23] J. P. Gilday, J. C. Gallucci, L. A. Paquette, *J. Org. Chem.* **1989**, *54*, 1399–1408.

[24] A. G. Brook, *Acc. Chem. Res.* **1974**, *7*, 77–84; A. Wright, R. West, *J. Am. Chem. Soc.* **1974**, *96*, 3227–3232.

[25] T. Ruhland, R. Dress, R. W. Hoffmann, *Angew. Chem.* **1993**, *105*, 1487–1489; *Angew. Chem. Int. Ed. Engl.* **1993**, *32*, 1467; H. J. Reich, R. R. Dykstra, *Angew. Chem.* **1993**, *105*, 1489–1491; *Angew. Chem. Int. Ed. Engl.* **1993**, *32*, 1469.

[26] W. Mikenda, *Vibrational Spectroscopy*, **1992**, *3*, 327–330.

[27] K. Laumen, M. P. Schneider, *J. Chem. Soc., Chem. Commun.* **1988**, 598–600.

[28] E. Downer, J. Kenyon, *J. Chem. Soc.* **1939**, 1156.

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