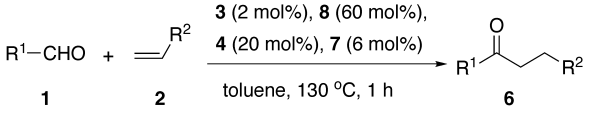
Table 1. The reaction of various aldehydes and olefins.



1 2 6

Entry	R^1 (**1**)	R^2 (**2**)[a]	Product	Yield [%][b]
1	Ph (**1a**)	*n*-C_4H_9 (**2a**)	**6a**	98 (100)
2	Ph (**1a**)	*n*-C_3H_7 (**2b**)	**6b**	83 (86)
3	Ph (**1a**)	*n*-C_6H_{13} (**2c**)	**6c**	99 (100)
4	Ph (**1a**)	*t*Bu (**2d**)	**6d**	84 (87)
5	Ph (**1a**)	Me_3Si (**2e**)	**6e**	95 (100)[c]
6	Ph (**1a**)	C_6F_5 (**2f**)	**6f**	98 (100)[d]
7	Ph (**1a**)	$PhOCH_2$ (**2g**)	**6g**	95 (100)[d]
8	*p*$MeOC_6H_4$ (**1b**)	*n*-C_4H_9 (**2a**)	**13**	79 (80)
9	*p*$CF_3C_6H_4$ (**1c**)	*n*-C_4H_9 (**2a**)	**6h**	71 (86)
10	*p*$Me_2NC_6H_4$ (**1d**)	*n*-C_4H_9 (**2a**)	**6i**	60 (64)
11	PhC_6H_4 (**1e**)	*n*-C_4H_9 (**2a**)	**6j**	95 (98)
12	$PhCH_2CH_2$ (**1f**)	*n*-C_4H_9 (**2a**)	**6k**	71[e]

[a] Five equivalents based on aldehyde were used. [b] Yield of product after isolation; GC yields are given in parenthesis. [c] 1.1 equivalents of **2e** was used. [d] Reaction time was 40 min. [e] 10% of the aldol condensation product of **1f** was obtained.

In summary, we have presented an efficient catalytic system for intermolecular hydroacylation. Further work is now directed toward understanding the mechanistic details of this reaction.

Experimental Section

Typical procedure for preparation of ketone **6a** (Table 1, entry 5): A screw-capped pressure vial (1 mL) was charged with freshly purified benzaldehyde (**1a**, 0.5 mmol), 2-amino-3-picoline (**4**, 0.1 mmol), benzoic acid (**7**, 0.03 mmol), aniline (**8**, 0.3 mmol), 1-hexene (**2a**, 2.5 mmol), and toluene (80 mg). After the mixture had been stirred at room temperature for several minutes, $[Rh(PPh_3)_3Cl]$ (**3**, 0.01 mmol) was added, and then it was stirred at 130 °C for 1 h. After cooling the reaction mixture to room temperature, it was purified by column chromatography (SiO_2, *n*-hexane/ethyl acetate 4/1) to yield pure **6a** (0.49 mmol, 98% yield).

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[5] To confirm the effect of carboxylic acid, the hydroacylation of 1-hexene with freshly purified benzaldehyde was performed with benzoic acid under the reaction conditions depicted in Equation (1). While it took 24 h to obtain a 72% yield without benzoic acid, the reaction time was shortened to 6 h with benzoic acid, and a 75% yield of heptanophenone **6a** was obtained.

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[7] The reactivity of **2a** with **9** towards hydroiminoacylation was not enhanced by the addition of **7**. This implies that carboxylic acid does not affect the hydroiminoacylation step. Therefore, we assume that the rate-determining step is the formation of **9**.

[8] It is also possible that **1a** condenses with **4** to form **9**. However, the condensation of **1a** with **8** is more facile than with **4**. When an equimolar mixture of **1a**, **4**, and **8** was heated at 130 °C for 10 min **1a** was completely consumed and the ratio of **9**:**11** was determined as 10:90 by GC.

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[12] It can be explained by the fact that the protonated aldimine is more electrophilic than the aldehyde. Since the aldimine is more basic than the aldehyde, it is the dominant reactant in the presence of acid.

Asymmetric Synthesis of a Chiral Secondary Grignard Reagent**

Reinhard W. Hoffmann,* Bettina Hölzer, Oliver Knopff, and Klaus Harms

Chiral organometallic reagents are of interest in stereoselective synthesis. This holds in particular for chiral α-heterosubstituted organolithium and Grignard reagents.[1] However, their reactions with electrophiles do not always take a stereochemically homogenous pathway. It is not clear

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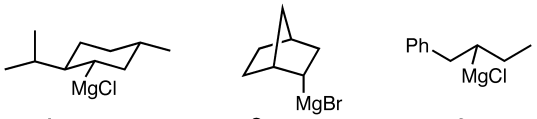
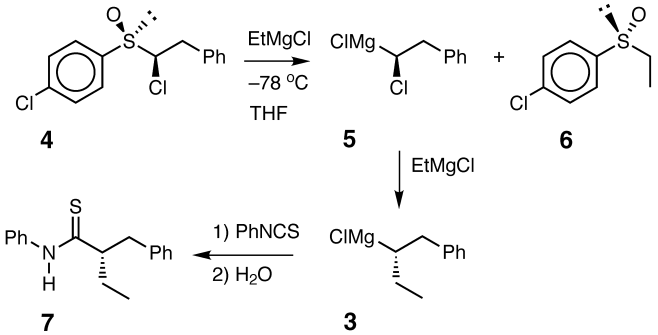
whether the result (inversion, retention, or partial racemization) is predominantly due to the nature of the electrophile or to which extent the presence of the heteroatom in the α-position is involved in the stereochemical outcome. Clearer information on the intrinsic stereochemical course of reactions of organolithium and Grignard reagents with electrophiles could be obtained if "unsubstituted" chiral Grignard reagents were available. In this context reagents such as **1**[2] or **2**[3] should be suitable. Since **1** and **2** have, however, more than



1 **2** **3**

one stereogenic center, it remains open, to which extent the stereochemical course of the reaction of Grignard reagents **1** or **2** depends on the chirality of the molecular backbone. Unambiguous results could therefore be obtained if simple chiral secondary Grignard reagents such as **3** could be used for stereochemical studies. We report here on the "synthesis" of the Grignard reagent **3** (>90% *ee*) and the stereochemistry of its oxidation to the secondary alcohol **8** (see Table 1).

Enantiomerically pure Grignard reagents such as **3** are not accessible from enantiomerically pure secondary alkyl halides by reaction with magnesium metal,[4] since electron transfer processes and the intervention of radicals[5] annihilates the stereochemical information. Likewise, neither halogen/magnesium nor sulfoxide/magnesium exchange reactions can be used to generate **3**, because the latter as a simple secondary Grignard reagent is too rich in energy to allow its generation in a thermodynamically driven Grignard exchange reaction. A reaction which is suitable for the generation of **3** is the carbenoid homologation reaction[6] using α-haloalkyl Grignard reagents **5** as a starting point. The route to generate enantiomerically pure secondary Grignard reagents **3** was open, once we succeeded in generating the enantiomerically pure α-chloroalkyl Grignard reagent **5** by a sulfoxide/magnesium exchange reaction on diastereomerically pure α-chloroalkyl sulfoxide **4**.[7] Subsequent reaction of **5** with an excess



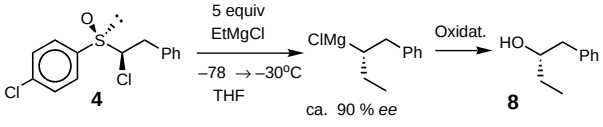
4 **5** **6** **7** **3**

of ethylmagnesium chloride between -50 and $-30\,^{\circ}C$ furnished the desired Grignard reagent **3**. *Ethyl*magnesium *chloride* was chosen for two reasons: First, racemization of the intermediate **3** is slowest if chloride, as an anion of low nucleophilicity, is present.[8] Second, the carbenoid homologation reaction of **5** to give **3** is least complicated by formation of a "rearranged" Grignard product,[9] if *ethyl*magnesium halide is used in THF.

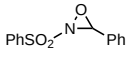
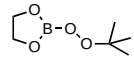
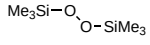
The solution of **3** generated by reaction of the sulfoxide **4** with an excess of ethylmagnesium chloride (5–10 equiv)[10] was quenched with phenylisothiocyanate at $-78\,^{\circ}C$ and subsequently allowed to warm to room temperature resulting in the formation of 56% of the thioamide **7**. HPLC showed **7** to be of 93% *ee*. From the solution of **7** a small amount of crystalline material was obtained, identified by HPLC as **7** of 78% *ee*. X-ray structure analysis[11] of one of these crystals and HPLC analysis of this particular crystal allowed the assignment of the absolute configuration of the major enantiomer of **7** as shown. This demonstrates that the carbenoid homologation reaction of **5** to give **3** proceeded with inversion of configuration.[12] We attribute the small loss in enantiomeric purity to a competing racemization at the stage of the intermediate **5**. The secondary Grignard reagent **3** appears to be configurationally stable at $-78\,^{\circ}C$. Warming of the solution of **3** to $-10\,^{\circ}C$, however, leads to slow racemization in a first order process with $k = (3.46 \pm 0.05) \times 10^{-5}\ s^{-1}$ corresponding to a half life of about 5 h. This holds for the Grignard reagent **3** in the given solvent and reaction mixture. For comparison, the epimerization of **2** to *exo*-norbornylmagnesium bromide occurs at room temperature in diethyl ether with a half life of about 5 h.[3, 13]

Access to the Grignard reagent **3** with known absolute configuration[12] and an enantioselectivity of about 90% *ee* allows the study of the stereochemical course of the reaction of Grignard reagents and provides more detailed mechanistic insights. We illustrate this with reference to the oxidation of **3** to give the secondary alcohol **8** (Table 1). The absolute configuration of the laevorotatory alcohol is known.[14] Oxidation of organolithium and Grignard reagents may occur by the transfer of an oxygen atom, but may also be initiated by electron transfer to the oxidizing agent. The stereochemical

Table 1. Stereochemical course of the oxidation of the Grignard reagent **3** to the alcohol **8**.



4 **8**

Oxidant		Yield (**8**) [%]	*ee* (**8**) [%]
$MoO_5 \cdot Py \cdot DMPU$[a]	**9**	84	92
	**10**	80	91
	**11**	80	88
	**12**	20	82
$Ti(OiPr)_4/tBuOOH$	**13**	82	71
		75	32
O=O		89	15

[a] Py = Pyridine, DMPU = *N*,*N*′-dimethylpropylene urea.

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course of the oxidation of **3** to the alcohol **8** reveals (cf. Table 1) that depending on the nature of the oxidizing agent the one or the other mechanism may predominate. The molybdenum peroxide **9**,[15] the Davis oxaziridine **10**,[16] and the peroxyborate **11**[17] oxidize **3** to **8** under retention of configuration and essentially complete retention of the enantiomeric purity (>90%). On oxidation with bis(trimethylsilyl)peroxide **12**[18] racemization occurs to a noticeable extent. Extensive racemization was observed on oxidation of **3** with the peroxotitanium reagent **13**,[19] with lithium *tert*-butylhydroperoxide,[20] or with dioxygen.

We have described here a route to an enantiomerically enriched chiral secondary Grignard reagent **3** which may serve as a probe to give insights into the mechanisms of Grignard reactions, as demonstrated by the stereochemistry of its oxidation to the alcohol **8**.

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[10] The reaction of the sulfoxide **4** to give the Grignard reagent **3** requires at least three equivalents of ethylmagnesium chloride, since the sulfoxide coproduct **6** consumes a further equivalent of ethylmagnesium chloride leading to the formation of diethyl sulfoxide and *p*-chlorophenylmagnesium chloride. We applied more than three equivalents of ethylmagnesium chloride in order to increase the rate by which **5** is converted into **3**, thereby reducing the fraction of **5** which underwent competing racemization.

[11] Crystallographic data (excluding structure factors) for the structures reported in this paper have been deposited with the Cambridge Crystallographic Data Centre as supplementary publication no. CCDC-143893. Copies of the data can be obtained free of charge on application to CCDC, 12 Union Road, Cambridge CB2 1EZ, UK (fax: (+44) 1223-336-033; e-mail: deposit@ccdc.cam.ac.uk).

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Unusually Stable Vinyl Cations**

Thomas Müller,* Rita Meyer, Dirk Lennartz, and Hans-Ullrich Siehl

Dedicated to Professor Paul von Ragué Schleyer on the occasion of his 70th birthday

Recent progress in silylium ion chemistry[1] has opened a novel route for the synthesis of stable carbocations in arene solvents at room temperature. The addition of an arene complex of triethylsilylium to the C=C bond in 1,1-diphenyl ethene has been used to generate a room-temperature stable β-silyl-substituted carbenium ion.[2, 3] Similarly, we have used the intramolecular addition of a silylium ion to a C=C bond to generate the 2-silanorbornyl cation.[4] Vinyl cations,[5] dicoordinated carbocations in which the positive charge is located at a sp-hybridized carbon of a double bond, have been established as reaction intermediates in numerous reactions, such as the solvolysis of activated haloalkenes[6] and alkenes bearing super leaving groups like triflate and nonaflate[7] and protonation reactions of alkynes and allenes.[8] Some persistent vinyl cations have been generated by protonation of alkynes[9] and allenes[10] in superacidic media at temperatures below $-100\,^{\circ}C$. These cations have been characterized by NMR spectroscopy supported by quantum-mechanical calculations. Herein we report the synthesis of unusually stable vinyl cations by intramolecular addition of transient silylium ions to C≡C bonds.

Hydride transfer[11] between 1-alkyl- and 1-aryl-substituted 3,7-disila-3,3,7-dimethyl-octyne-1 (**1**) and trityl cation in benzene is expected to give silylium ion **2** as the first intermediate. The silylium ion **2** may react intermolecularly

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