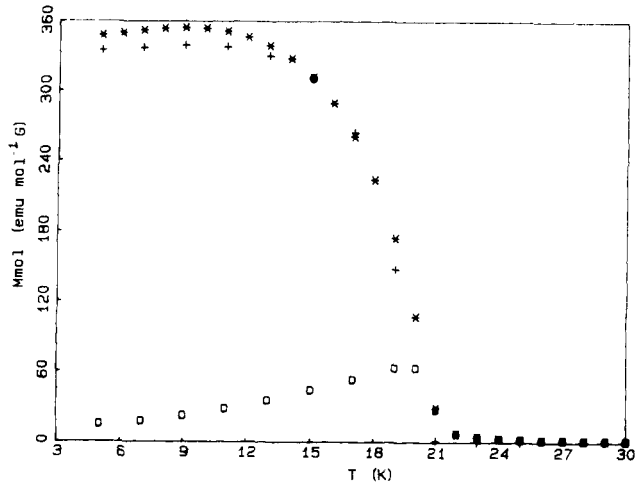

Figure 2. (*) FC magnetization; (+) remnant magnetization; (O) ZFC magnetization of $[Mn(F_5Benz)_2]_2NITEt$ in low field (H = 1 Oe).

either chain or layer structures can be built, but it is not possible to suggest a crystal structure owing to the large number of different coordination modes of the carboxylates.

If we compare the χT values in the paramagnetic region of $[Mn(F_5benz)_2]_2NITR$ with those of the ferrimagnetic manganese radical chains we see that the values for the latter start to increase at higher temperature than those of the two present compounds suggesting that in these the coupling is smaller. On the other hand, the powder EPR spectra of $[Mn(F_5benz)_2]_2NITR$ show a single line at $g = 2$ which is much narrower than those observed for $Mn(hfac)_2NITR$ chains (35 G against 150 G) implying that the exchange narrowing regime is more efficient for the present compounds.[15,16] These results can be attributed to a magnetic dimensionality larger than one for $[Mn(F_5benz)_2]_2NITR$, which makes the narrowing mechanism more efficient than in linear chain systems.

Below 40 K an abrupt increase in the slope of χT is observed, suggesting that the system approaches a magnetic phase transition. Low field (0–1 Oe) magnetization measurements were performed with a SQUID magnetometer,[17] and the results for $[Mn(F_5benz)_2]_2NITET$ are shown in Figure 2. The data show that the compound orders three dimensionally below 20.5 K. Analogous measurements on $[Mn(F_5benz)_2]_2NITMe$ show a transition at 24 K. In Figure 2 we report also the remnant and the zero field cooling (ZFC) magnetizations. Both the high remnant magnetization and the low ZFC one indicate scarce mobility of the domain walls. This may be due to the fact that the measurements were performed on polycrystalline powders. The hysteresis loop at 4.2 K, shown in Figure 3 for $[Mn(F_5benz)_2]_2NITMe$, indicates that both the coercitive field and the residual magnetization are fairly large. Moreover fluxmetric measurements at 4.2 K have shown that for both compounds the remnant magnetization is stable in time.

Magnetization curves at 10 K in the field range 0.5–45 KOe show an initial saturation to $M \cong 5000$ emu mol^{-1} G in a field of 500 Oe, then a second saturation to $M \cong 10000$ emu mol^{-1} G in a field of 10000 Oe and finally a linear increase without reaching a saturation in the maximum field available of 45000 Oe, inducing as to exclude the ferromagnetic nature of the transition. The slopes of the $M(H)$ curves above 10 kOe indicate the presence of antiferromagnetic interactions whose value can be roughly evaluated from the equation[18]

$$\chi_\perp = \frac{dM}{dH} = \frac{N_g^2\mu_B^2}{2z|J_{AF}|}$$

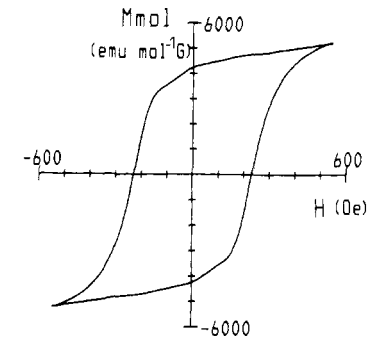

Figure 3. Hysteresis loop for $[Mn(F_5Benz)_2]_2NITMe$ at 4.2 K.

yielding $2z|J_{AF}|/k \simeq 4$ K, where z is the number of nearest neighbors.

These data are in agreement with either ferrimagnetism or weak ferromagnetism. Spin canting has previously been observed in manganese(II) compounds[19,20] and has been attributed to local anisotropy (i.e., the principal axes of the zero field splitting tensor are not equally oriented for ions occupying not equivalent positions). If we consider the value of magnetization reached in low magnetic field (500 Oe) as corresponding to the saturation of the magnetic moments arising from the misalignment of the spins we find that it corresponds to an unusually high value of canting.

A ferrimagnetic structure with a net moment lower than that expected for spin $S = 5/2 + 5/2 - 1/2$ can explain the present data, but no unique choice is possible due to the lack of information on the crystal structure and of single crystal measurements.

The present results show that substitution of hexafluoroacetylacetonates with carboxylates in manganese radical species increases dramatically the magnetic transition temperature, raising it at the highest value so far reported in molecular materials which have a well defined and constant chemical analysis.

(15) Richards, P. M. In *Local Properties at Phase Transition*; Editrice Compositori: Bologna, Italy, 1975.
(16) Hennessy, M. J.; McElwee, C. D.; Richards, P. M. *Phys. Rev. B* **1973**, *7*, 930.
(17) Beauvillain, P.; Chappert, C.; Renard, J. P. *J. Phys. E.: Sci. Instrum.* **1985**, *18*, 839.
(18) Morrish, A. H. *The Physical Principles of Magnetism*; John Wiley & Sons Inc.: New York, 1966.
(19) Borovik-Romanov, A. S.; Orlova, M. P. *J. Expt. Theor. Phys. (URSS)* **1956**, *31*, 579.
(20) Flippen, R. B.; Friedberg, S. A. *Phys. Rev.* **1961**, *121*, 1591.

Total Synthesis of (+)-Koumine, (+)-Taberpsychine, and (+)-Koumidine

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(−)-Koumine (**1**), the principal medicinal constituent of the Chinese plant *Gelsemium elegans* Benth., was first isolated in 1931.[1] In 1981 its structure was elucidated by single-crystal X-ray crystallography.[2] The absolute stereochemistry[3] was established by partial synthesis from vobasine.[4] Here we report the total

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(1) Chou, T. Q. *Chinese J. Physiol.* **1931**, *5*, 345; *Chem. Abst.* **1932**, *26*, 806.
(2) Liu, C.; Wang, Q.; Wang, C. *J. Am. Chem. Soc.* **1981**, *103*, 4634. Khuong L. F.; Chiaroni, A.; Riche, C. *Tetrahedron Lett.* **1981**, *22*, 733.
(3) Zhujin, L.; Qiansheng, Y. *Youji Huaxu* **1986**, *1*, 36.
(4) Büchi, G.; Manning, R. E.; Monti, S. A. *J. Am. Chem. Soc.* **1964**, *86*, 4631.

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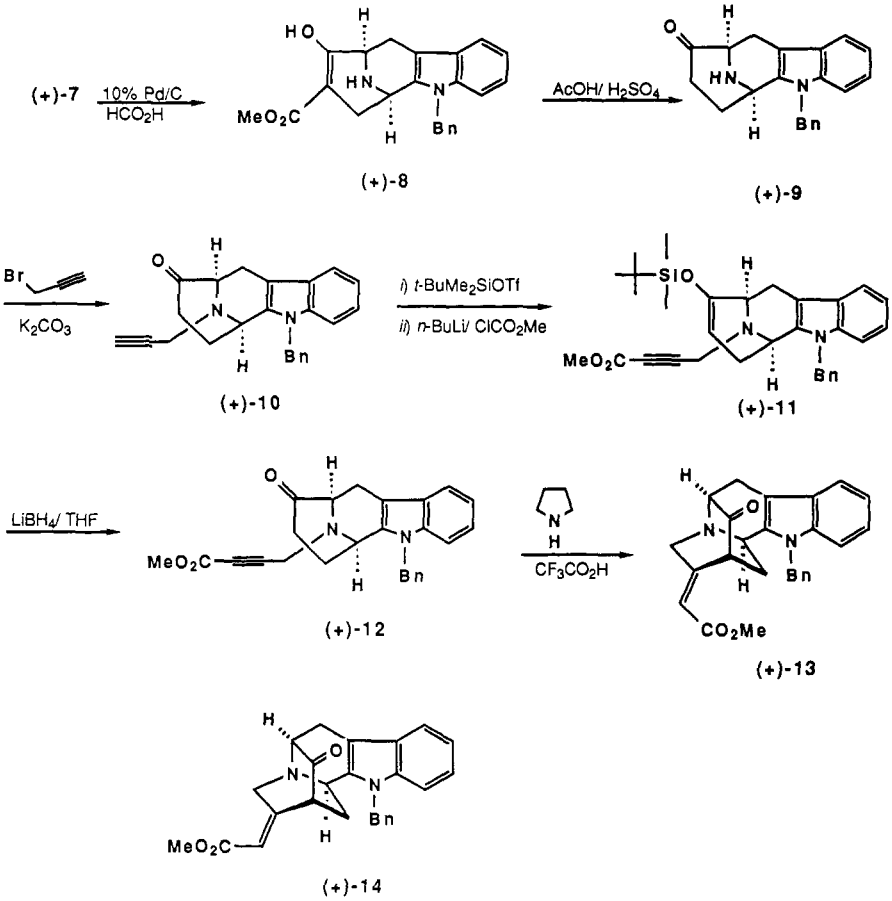
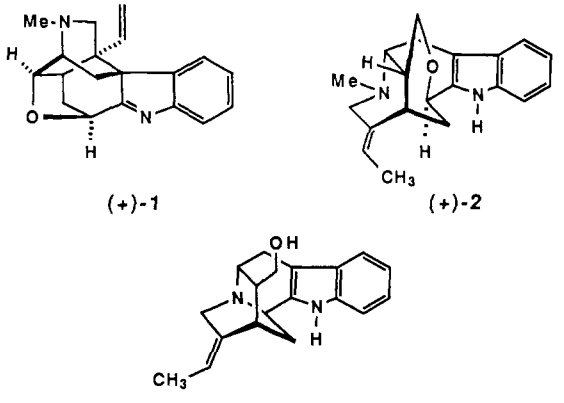
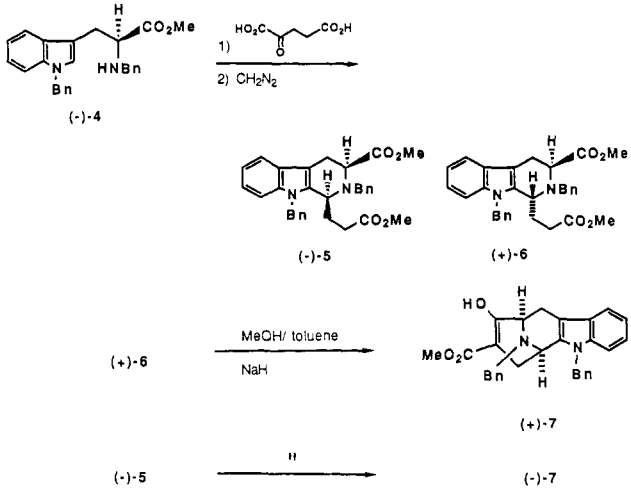
Scheme I



synthesis of (+)-koumine (**1**) and enroute (+)-taberpsychine (**2**)[5] and (+)-koumidine (**3**).[6]



S-(−)-Tryptophan was converted into the derivative **4** by adaptation of standard transformations in an overall yield of 72% through four steps.[7] Condensation of **4** with 2-ketoglutaric acid (PhH/*p*-dioxane, 80 °C) followed by treatment with diazomethane gave **6** (58%). Chromatography of the mother liquor also gave **5** (30%).[8] Treatment of **5** with MeOH/NaH/toluene/reflux/4



h gave (−)-**7** (88%), $[\alpha]^{25}_D$ −158° (*c* 0.99 in CH_2Cl_2), and, similarly, treatment of **6** with MeOH/NaH/toluene/reflux/13.5 h gave (+)-**7** (84%), $[\alpha]^{25}_D$ +160° (*c* 0.98 in CH_2Cl_2).[9] Obviously **6** can only undergo intramolecular Dieckman cyclization by prior epimerization at C-3, resulting in (+)-**7**. Consequently both antipodes of **7** were readily accessible starting with (−)-tryptophan. Only the series derived from (+)-**7** will be reported.[10]

(5) Taberpsychine (**2**) was isolated from *Tabernaemontana psychotrifolia* H.B.K.: Biemann, K.; Spiteller, *J. Am. Chem. Soc.* **1962**, *84*, 4578. Its structure was reported in 1969 under the name of anhydrovobasindiol, and it was partially synthesized from vobasine. Dugan, J. J.; Hesse, M.; Renner, U.; Schmid, H. *Helv. Chim. Acta* **1969**, *52*, 701. Burnell, R. H.; Medina, J. D.; *Can. J. Chem.* **1971**, *49*, 307.

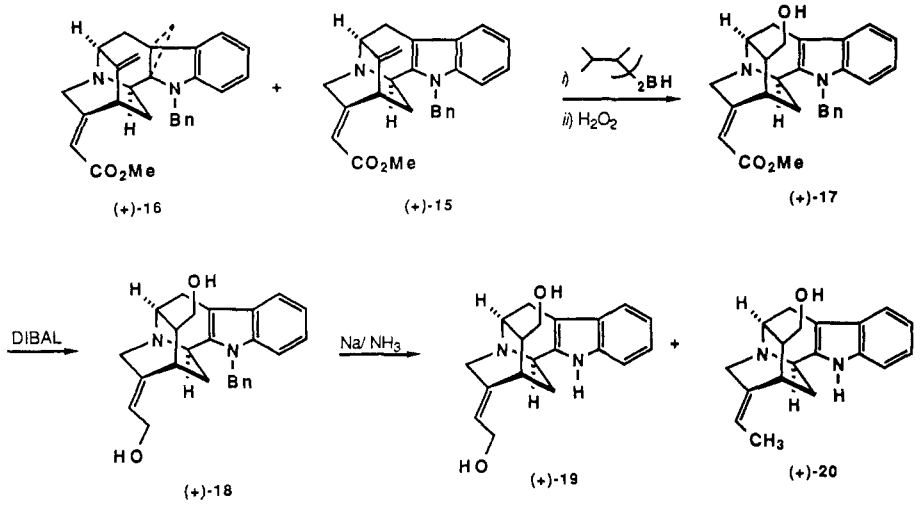
(6) Koumidine (**3**) was first isolated from Chinese Gelsemium (*G. elegans*): Jin, H. L.; Xu, R. S. *Acta Chim. Sinica* **1982**, *40*, 112. The geometry of the ethylidine group was recently corrected by Cordell. Schum, Y.; Cordell, G. A. *Phytochemistry* **1987**, *24*, 2875.

(7) Hobson, J. D.; Raines, J.; Whiteoak, R. J. *J. Chem. Soc.* **1963**, 3495. Yoneda, N. *Chem. Pharm. Bull.* **1965**, *13*, 1231. Cloudsdale, I. S.; Kluge, A. F.; McClure, N. L. *J. Org. Chem.* **1982**, *47*, 919. For a recent similar example, see: Zhang, L.-H.; Cook, J. M. *Heterocycles* **1988**, *27*, 1357. Hagen, T. J.; Cook, J. M. *Tetrahedron Lett.* **1988**, *29*, 2421.

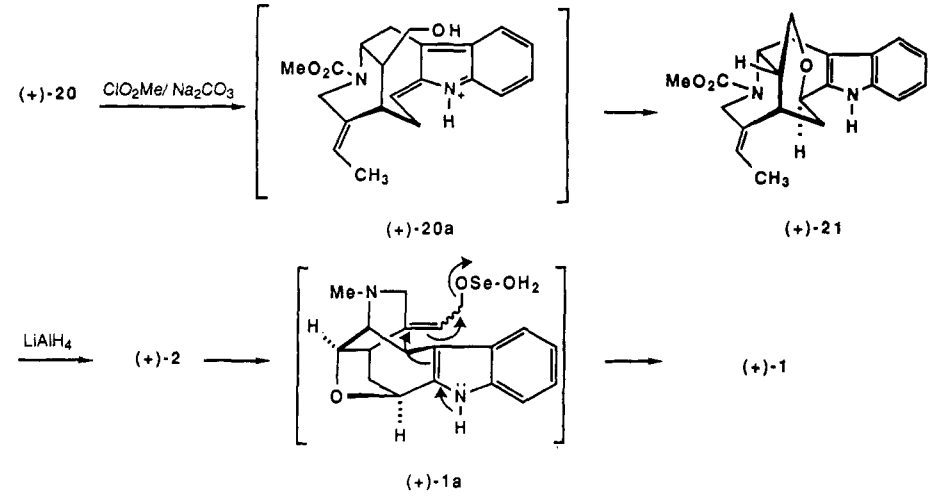
(8) The assignment of the relative stereochemistry is based upon ^{13}C NMR correlations described for 1,2,3-trisubstituted tetrahydro-β-carbolines. The *N*-benzylmethylene carbon for 1,3-cis-disubstituted systems appears 7 ppm downfield from the trans isomer (+)-**6** (1*R*, 3*S*), 52.63; (−)-**5** (1*S*, 3*S*), 61.15 ppm. Bailly, P. D.; Hollinshead, S. P. *Heterocycles* **1987**, *26*, 389.

(9) The enantiomeric purities were shown to be >95% ee by ^1H NMR in the presence of the chiral solvating agent (*S*)-(+)-2,2,2-trifluoro-1-(9-anthryl)ethanol in benzene-d_6.

Scheme II



Scheme III



Hydrogenolysis of (+)-**7** using 10% Pd/C/HCO_2H gave (+)-**8** (72%), which was heated in aqueous $AcOH/H_2SO_4$ to give (+)-**9** (86%), $[\alpha]^{25}_D$ +98° (*c* 1.08 in CH_2Cl_2). *N*-Propargylation of (+)-(**9**) to give (+)-**10** (89%) was achieved by treatment with propargyl bromide/K_2CO_3/EtOH. Exposure of (+)-**10** to *t*-$BuMe_2SiOTf/NEt_3$/0 °C/CH_2Cl_2 followed by *n*-BuLi/THF/−78 °C/$ClCO_2Me$ gave (+)-**11** (78%). Treatment of (+)-**11** with *n*-$Bu_4N^+F^-$/THF/−78 °C afforded (+)-**13** and (+)-**14** in low yields and in an irreproducible manner. However hydrolysis of (+)-**11** using $LiBF_4$/THF gave (+)-**12** (86%) which was efficiently cyclized to (+)-*E*-**13** (68%) and (+)-*Z*-**14** (12%) by treatment with pyrrolidine (0.2 equiv)/CF_3CO_2H (0.2 equiv)/PhH/reflux.[11] The structure and stereochemistry of **14** was confirmed by single-crystal X-ray crystallography.[12]

At this stage we needed to homologate the carbonyl group of **13** into a hydroxymethyl function in a stereospecific manner. Treatment of (+)-**13** with $CH_2Br_2/Zn/TiCl_4$/15 °C gave the required exomethylene adduct (+)-**15** (70%), along with some of the unexpected 2,3-cyclopropyl adduct (+)-**16** (13%).[13] Hydroboration of (+)-**15** (diisoamylborane/DME/0 °C) followed by oxidative workup gave (+)-**17** (69%). The structure of (+)-**17** was confirmed by single-crystal X-ray crystallography.[12]

Reduction of (+)-**17** with DIBAL/PhH/25 °C gave the allylic alcohol (+)-**18** (90%) which was debenzylated by treatment with Na/NH_3/THF/−30 °C. Two products were isolated: the diol (+)-**19** (36%)[14] and the double hydrogenolysis product (+)-**20** (43%). The compound **20** is the *E*-isomer of koumidine (**3**). When the reductive debenzylation was carried out at −78 °C, the only isolable product was (+)-**19** (75%).

When (+)-**20** was treated with methylchloroformate/Na_2CO_3 (aqueous)/25 °C, it gave *N*-carbomethoxy-*N*-desmethyl taberpsychine (+)-(**21**) (56%), presumably via the extended immonium ion **20a**.

Reduction of (+)-**21** with $LiAlH_4$/THF/22 °C gave (+)-taberpsychine (**2**) (70%). Comparison of (+)-**2** with an authentic sample of (−)-**2** (^1H NMR, MS, IR, mp) equal and opposite $[\alpha]^{25}_D$ +296° (*c* 0.110 in MeOH) confirmed the identity of taberpsychine and in particular the geometry of the ethylidine group. At this stage formal total synthesis of (+)-koumine (**1**) was also completed since (−)-taberpsychine has been converted into (−)-koumine by treatment with $SeO_2/H_2O_2/H_3O^+$ presumably through the SN2′ process depicted for **1a**.[15]

Compound (+)-*E*-**14** was then carried through the same series of transformations, and in the reductive debenzylation process we

(10) All structures are drawn in their correct absolute configuration. By choosing (+)-**7** we have synthesized the antipodes of the natural alkaloids.

(11) This Michael addition is readily reversible. Solutions of **13** and **14** revert to a 68:12 **13**/**14** mixture upon standing.

(12) The complete details of the single-crystal X-ray structural determinations of **14** and **17** may be obtained from Dr. John Huffman, Molecular Structure Center, Indiana University, IN 47405. Please ask for structure report numbers 87152 and 88047, respectively.

(13) Lombardo, L. *Tetrahedron Lett.* **1982**, *23*, 4293.

(14) The compound **19** is known as 18-hydroxydesoxysarpagine: Lounasmaa, M.; Koskinen, A. *Planta Medica* **1982**, *44*, 120.

(15) Zhujin, L.; Qiansheng, Y. *Youji Huaxu* **1986**, *1*, 36. The only previous work in this area of indole alkaloid chemistry is as follows: Sakai, S.; Yamanaka, E.; Kitajima, M.; Yokota, M.; Aimi, N.; Wongseripatana, S.; Ponglux, D. *Tetrahedron Lett.* **1986**, *27*, 4585. Liu, S.; Sun, Q.; Yu, Q. *J. Org. Chem.* **1983**, *48*, 44.

isolated (+)-koumidine (**3**).[6] Its ^{1}H NMR, IR, MS, mp were identical with an authentic sample of (−)-koumidine, but it had an equal and opposite $[\alpha]^{25}_D$ +11.1° (*c* 0.360 in MeOH).

The alkaloids of the koumine-sarpagine group which also includes gelsemine have not yielded to total synthesis. The crucial intramolecular Michael reaction[16] [**12** into **13**/**14**] offers a new way for making quinuclidines that may be valuable in other areas of alkaloid synthesis.[17]

Acknowledgment. The National Institutes of Health are gratefully thanked for their support, and Dr. B. B. Mugrage thanks the NIH for a post doctoral fellowship (GM-12226). Professor M. Hesse and Professor G. Cordell are warmly thanked for authentic samples of (−)-taberpsychine and (−)-koumidine, respectively. Dr. John Huffman, Molecular Structure Center, Indiana University, Bloomington, IN 47405, is thanked for X-ray structural determinations.

(16) Trost, B. M.; Shuey, C. D.; DiNinno, F., Jr. *J. Am. Chem. Soc.* **1979**, *101*, 1284.
(17) All new compounds were characterized by ^{1}H NMR, ^{13}C NMR, IR, HRMS and/or microanalysis.

Generation of Chiral Organoaluminum Reagent by Discrimination of the Racemates with Chiral Ketone

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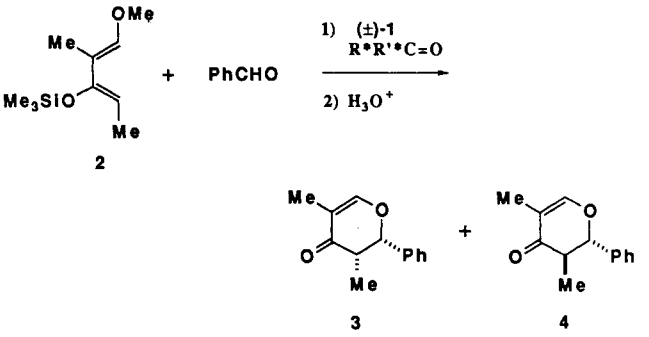
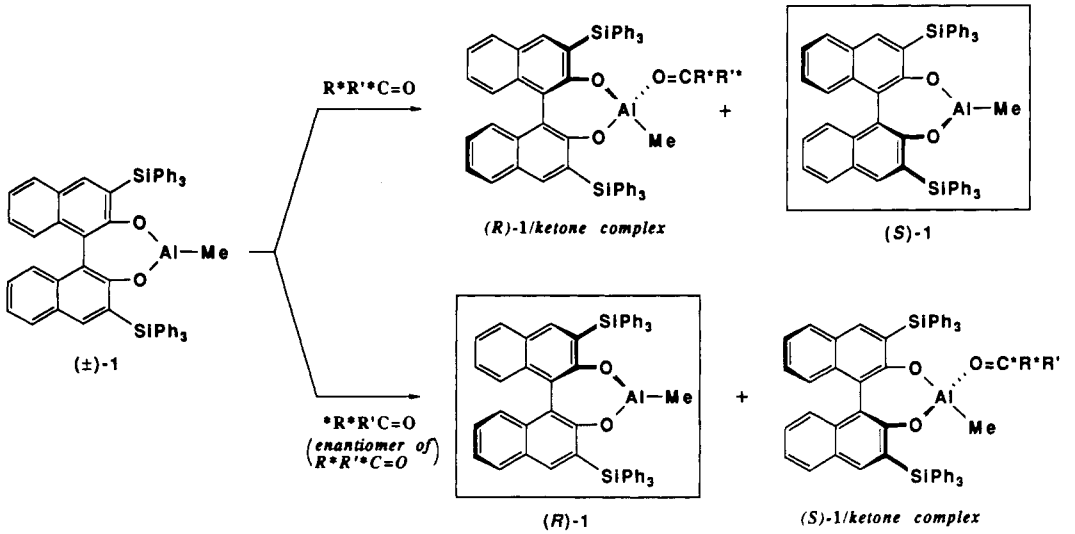
We have recently demonstrated a new, chiral organoaluminum catalyst which is highly effective for the introduction of chirality into cyclic as well as acyclic systems.[1,2] We also reported that bulky organoaluminum reagent MAD is capable of forming a selective 1:1 complex with specific carbonyl substrates.[3] One would therefore expect that certain chiral ketones may discriminate between racemic organoaluminum reagents of type **1** by diastereoselective complexation, and the remaining chiral organoaluminum reagent (*R*)-**1** or (*S*)-**1** would be utilized in situ as a chiral Lewis acid for asymmetric synthesis as illustrated in Scheme I. Here we wish to report our initial results of this study.

Our expectation has been realized by applying the in situ generated catalyst to the asymmetric hetero-Diels–Alder reaction as indicated in Table I. The racemic organoaluminum reagent (±)-**1** was prepared in CH_2Cl_2 as reported previously.[1] Sequential treatment of (±)-**1** with chiral ketone, the diene **2**, and benzaldehyde at −78 °C and stirring of the mixture at this temperature for 3 h afforded hetero-Diels–Alder adducts **3** and **4** after acidic workup. The optical yield of the major cis adduct **3** was determined by HPLC analysis after conversion to the (*R*)-MTPA ester. Note that with the enantiomerically pure organoaluminum reagent (*S*)-**1** the cis adduct **3** was obtained in 95% ee.[1]



Several characteristic features have been noted. (1) Among several terpene-derived chiral ketones examined, *d*-3-bromocamphor was found to be most satisfactory.[4-7] (2) Combination of (±)-**1** and chiral ketone in a 1:1 ratio gave a better result than that in a 2:1 ratio. This suggests that decomplexation of one enantiomeric organoaluminum reagent and the chiral ketone is more readily facilitated than that of the other diastereomeric complex by the addition of aldehyde, thereby allowing the enantioselective activation of the aldehyde for the asymmetric hetero-Diels–Alder reaction. Noteworthy is the fact that the catalytic use of the reagent exhibited higher enantioselection than the stoichiometric use. Although the extent of asymmetric induction in the hetero-Diels–Alder reaction is not yet as satisfactory as that with the optically pure **1**, one recrystallization of the cis adduct **3** of 82% ee (entry 8) from hexane gave the essentially pure **3** (>98% ee with ~60% recovery),[8] thereby enhancing the practicability of this method. (3) Since both *d*-3- and *l*-3-bromocamphor are commercially available, this method allows the synthesis of both enantiomers of hetero-Diels–Alder adducts in a predictable manner (entry 8 vs 9). *d*-3-Bromocamphor is responsible for the generation of (*S*)-**1**. (4) Use of toluene as solvent gave higher cis selectivity at the expense of enantiofacial selectivity (entry 6).

Scheme I



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