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Stereospecific 1,3-migration of an $Fe(CO)_3$ group on acyclic conjugated trienes bearing an electron-withdrawing group

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Abstract

Treatment of acyclic conjugated (η^4-4–7)-triene $Fe(CO)_3$ complexes bearing an electron-withdrawing group at a terminal position with a base such as $KN(SiMe_3)_2$ and NaH promoted 1,3-migration of an $Fe(CO)_3$ group on the triene, giving (η^4-2–5)-triene $Fe(CO)_3$ complexes. The 1,3-migration of an $Fe(CO)_3$ group is revealed to proceed in a stereospecific manner. © 1999 Elsevier Science Ltd. All rights reserved.

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Thus far, extensive research has been undertaken to construct stereogenic centers adjacent to the (diene)$Fe(CO)_3$ group[1] as well as to theoretically understand the factors governing the diastereoselectivity of the reactions.[2] Although the $Fe(CO)_3$ group is a very efficient chiral auxiliary for 1,2- and 1,3-asymmetric induction (AI), there are few examples that have achieved remote asymmetric induction[3] of higher than 1,4-AI. In order to overcome this drawback, several ingenious methods have been developed.[4] As an extension of the 1,2-migration of the $Fe(CO)_3$ group, which has already been reported by us,[5] we are currently interested in a 1,3-migration[6–9] of the $Fe(CO)_3$ group on triene complexes for constructing contiguous stereogenic centers. Our general strategy is shown in Scheme 1, which suggests the problem to be examined, that is, whether the 1,3-migration of the $Fe(CO)_3$ group on chiral triene complexes proceeds in a stereospecific manner or not. Herein we wish to report the stereospecific 1,3-migration of the $Fe(CO)_3$ group and the iterative functionalization of the migrated products with high stereoselectivity.

Although the 1,3-migration of the $Fe(CO)_3$ group has been reported under several conditions,[6–9] systematic and stereochemical studies on the metal shift were, to our knowledge, previously without example. First, 1,3-migration of the racemic triene complexes **1a**–**d**, bearing an electron-withdrawing group such as ester, ketone, and nitrile, was investigated under several conditions (Table 1). Although the ester complex **1a** was not transformed into the desired 1,3-migrated product **2a** under thermal[6] and Lewis-

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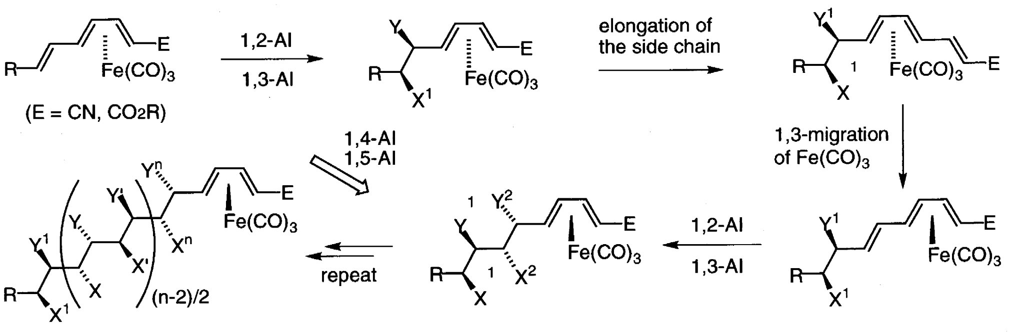


Scheme 1. The remote asymmetric induction (AI) using 1,3-migration of (diene)Fe(CO)$_3$ complexes

acidic[7] conditions, treatment of **1a** with 0.3 equiv. of potassium bis(trimethylsilyl)amide (KHMDS) at 0°C for 1 h gave **2a** in 71% yield along with the recovered starting material (entry 1). The potassium cation is crucial for the 1,3-migration reaction, because the corresponding lithium and sodium amide (LHMDS and NHMDS) were less effective under similar conditions (entries 2–3). In addition, weaker bases such as sodium hydride[8] could be used in place of KHMDS, if the reaction was performed at an elevated temperature and with a large amount of the base (entry 4). Thus, we found that the 1,3-migration of the Fe(CO)$_3$ group on the triene complex **1a** was induced by a catalytic amount of the base such as KHMDS and NaH. Similarly, the aldehyde and ketone complexes **1b** and **1c** were transformed into the corresponding migrated products **2b** and **2c** by the same treatment with KHMDS (entries 5 and 6). In contrast to the ester **1a**, the nitrile complex **1d** was less reactive to the base-catalyzed 1,3-migration under the above conditions (entry 7), resulting in recovery of most of the starting material as an *E*- and *Z*-isomeric mixture. However, subjection of **1d** to 2 equiv. of LiCH$_2$CN[9] at 0°C for 30 min led to exclusive formation of **2d** in 91% yield (entry 8).[10] In order to reveal the reaction mechanism of the base-catalyzed

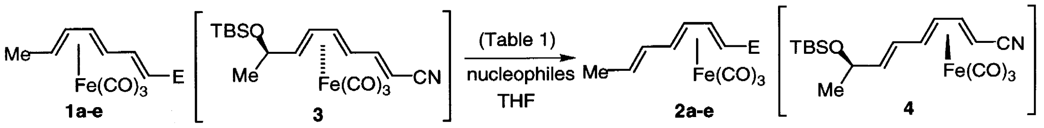


Table 1
1,3-Migration of the conjugated triene Fe(CO)$_3$ complexes **1a**–**e** and **3**[a]

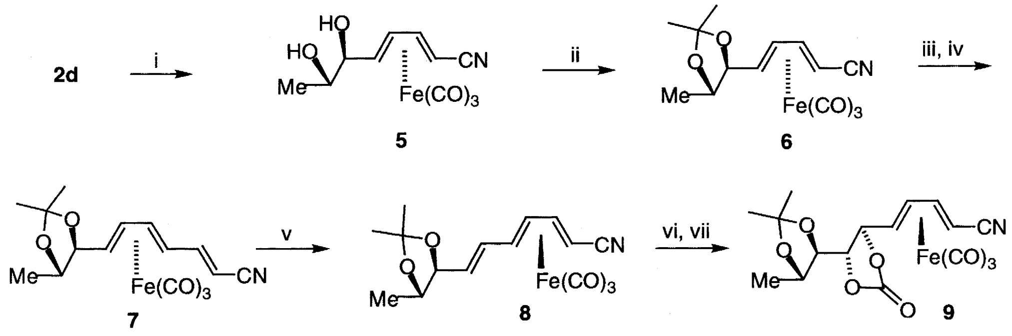
Entry	Substrate	Reaction Conditions	Yield (%)[b] Product	Yield (%)[b] Substrate
1	**1a** (E = CO$_2$Et)	KHMDS (0.3 eq.), 0 °C	**2a** (71)	**1a** (25)
2		NHMDS (0.2 eq.), 0 °C	**2a** (9)	**1a** (75)
3		LHMDS (0.9 eq), 0 °C	**2a** (2)	**1a** (89)
4		NaH (0.5 eq.), 0 °C, 1h	**2a** (78)	**1a** (15)
5	**1b** (E = CHO)	KHMDS (0.3 eq.), 0 °C	**2b** (39)[c]	**1b** (31)
6	**1c** (E = COMe)	KHMDS (0.3 eq.), 0 °C	**2c** (56)	**1c** (9)
7	**1d** (E = CN)	KHMDS (0.3 eq.), 0 °C	**2d** (18)[d]	**1d** (76)[d]
8		LiCH$_2$CN (2 eq.), -78 to 0 °C	**2d** (91)[d]	**1d** (trace)[d]
9	**3**	LiCH$_2$CN (3 eq.), -78 to 0 °C	**4** (63)	**3** (11)
10	**1e** (E = Ph)	LiCH$_2$CN (2 eq.), -78 to 0 °C	**2e** (trace)	**1e** (76)

a Reactions were performed in dry THF under a nitrogen atmosphere for 30 min, unless otherwise described. *b* Isolated yield, unless otherwise described. *c* Isolated as a mixture of (2*E*)- and (2*Z*)-adducts (ratio 35/4). *d* Calculated from the ^{1}H NMR spectra.

1,3-migration of the $Fe(CO)_3$ group, we next examined the stereochemical behavior of the $Fe(CO)_3$ group in the 1,3-migration of the chiral nitrile complex (4*S*,8*R*)-**3**. For this purpose, the same treatment of **3** with $LiCH_2CN$ (3 equiv.) as **1d** was conducted to give the migrated product **4** in 63% yield as a single diastereomer along with the recovered starting material **3** (entry 9).

By comparing the stereochemistry of (4*S*,8*R*)-**3** with that of (2*R*,8*R*)-**4**,[11] it is revealed that the $Fe(CO)_3$ group would migrate with inversion of configuration on the triene moiety. In contrast to **1a**–**d**, reaction of the benzylidene complex **1e** to $LiCH_2CN$ in THF (2 equiv. 0°C) gave no 1,3-migrated product (entry 10). Although it was revealed that the base-catalyzed 1,3-migration of the $Fe(CO)_3$ group requires an electron-withdrawing group on a triene moiety from the results described above, mechanistic details have not been clarified at this stage.[12]

We finally investigated an iterative utility of the 1,3-migration of the $Fe(CO)_3$ group for constructing contiguous stereogenic centers. The nitrile **2d** was employed as a starting material for this purpose. As shown in Scheme 2, the diol **5** was synthesized stereoselectively as an inseparable mixture (*anti*:*syn* 9:1) from **2d** by the OsO_4-mediated dihydroxylation.[13] After conversion of **5** into the acetonide **6**, the requisite nitrile **7** was prepared by the successive reduction and Horner–Emmons olefination. The second 1,3-migration of **7** proceeded smoothly under the same reaction conditions to give **8** in 65% yield. The OsO_4-mediated dihydroxylation of **8** occurred with high *anti*-selectivity (*anti*:*syn* 98:2) and the subsequent protection of the resulting diol gave rise to the 1,2-*syn*-2,3-*anti*-3,4-*syn* tetraol derivative **9**.[14]



Scheme 2. (i) OsO_4, pyridine; $NaHSO_3$, rt, 92% (β:α=9:1); (ii) $Me_2C(OMe)_2$, *p*-TsOH, $CHCl_3$, 78%; (iii) DIBAL-H, toluene, 92%; (iv) $(EtO)_2P(O)CH_2CN$, NaH, THF, 79% (*E*:*Z*=4.3:1); (v) $LiCH_2CN$, THF, −78 to 0°C, 65%; (vi) OsO_4, pyridine; $NaHSO_3$, 70% (β:α=2:98); (vii) $(imidazole)_2CO$, benzene, 82%

In conclusion, we have clarified the stereochemical outcome of the base-catalyzed 1,3-migration of the triene $Fe(CO)_3$ complexes and also demonstrated a novel iterative asymmetric induction method. Further studies for a more efficient functionalization of an uncomplexed olefin are currently in progress.

Acknowledgements

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10. In contrast to our result, the authors of Ref. 9a described that no 1,3-migration to **2d** was observed by treatment of **1d** with an excess reagent of $LiCH_2CN$ in THF.
11. The relative configuration of **4** was unambiguously determined by an X-ray crystallographic analysis of acetonide derivative, which had been transformed from **4** in three steps.
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14. The relative stereochemistry of **9** was unambiguously determined by an X-ray crystallographic analysis.