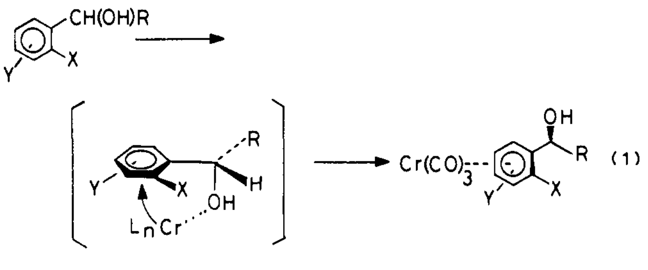
Diastereoselective $Cr(CO)_3$ Complexation of Arene Compounds Mediated by a Remote Hydroxyl Group

Motokazu Uemura,* Tatsuya Minami, and Yuji Hayashi

Faculty of Science, Osaka City University
Sugimoto 3-3-138
Sumiyoshi-ku, Osaka 558, Japan

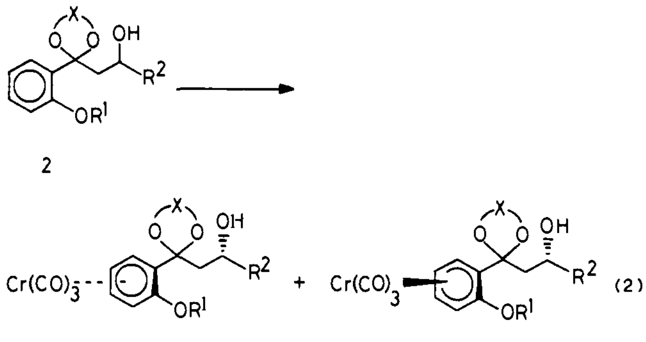
Received March 23, 1987

Diastereoselective synthesis of (η^6-arene)$Cr(CO)_3$ complexes of ortho or meta disubstituted aromatic compounds possessing a chiral center at the side chain is important in organic synthesis because of some characteristic properties of these chromium complexes such as nucleophilic addition to the complexed ring, stabilization of benzylic carbanions and carbonium ions, and steric bulkiness of $Cr(CO)_3$ group. We recently reported[1,2] that ortho-substituted secondary benzylic alcohol derivatives gave exclusively S^*,S^*–diastereomeric[3] chromium complexes via an intermediate **1** (eq 1). The chromium complexes of *o*-alkoxyphenyl alkyl ketones having a chiral center at the C-*n* position in the alkyl side chain could be effectively employed to control the stereochemistry of the C-1,*n* relationship with use of the following two reactions. The addition of nucleophiles to the benzylic carbonyl group of these type complexes proceeds stereoselectively,[2,4] and the resulting benzylic hydroxyl group is substituted via $Cr(CO)_3$-stabilized carbonium ions with stereochemical retention.[2] In this communication, we disclose diastereoselective $Cr(CO)_3$ complexation of *o*-alkoxyphenyl derivatives having two functional groups in the acyclic part, an acetal at the C-1 position, and the hydroxyl group at the C-2 or C-3 position, for the purpose of development of acyclic stereocontrol utilizing the transition metal complexed molecules.



1

Since 3-hydroxy-1-(*o*-methoxyphenyl)-1-pentanone gave no corresponding arene chromium complex by the reaction with $Cr(CO)_6$ or (naphthalene)$Cr(CO)_3$,[5] the benzylic carbonyl group was protected as an acetal for the $Cr(CO)_3$ complexation reaction.[6] The reaction of 3-hydroxy-1-(*o*-methoxyphenyl)-1-pentanone ethylene acetal (**2**) (R^1 = Me, R^2 = Et, X = CH_2CH_2) with $Cr(CO)_6$ in butyl ether, heptane, and THF (10:1:1) at 130–140 °C for 24 h gave an easily separable diastereomeric mixture of a less polar S^*,R^*-complex **3**[7] (mp 125 °C) and a more polar R^*,R^*-complex **4**[7] (mp 98 °C) in a ratio of 55:45 in 75% yield. Since this type of thermal complexation with $Cr(CO)_6$ reaches equilibrium during the long reaction time,[8] a kinetic complexation under milder conditions is required to obtain higher diastereoselectivity. Thus, the treatment of **2** (R^1 = Me, R^2 = Et, X = CH_2CH_2) with (naphthalene)$Cr(CO)_3$[9] in ether containing 1 equiv of THF at 70 °C in a sealed tube afforded predominantly S^*,R^*-complex **3** (R^1 = Me, R^2 = Et, X = CH_2CH_2) in a ratio of 89:11 (eq 2). The naphthalene–chromium bond is labile, and the naphthalene ligand undergoes facile slippage freeing a coordination site ($\eta^6 \rightarrow \eta^4$) for an incoming ligand.[9] This path is accelerated by Lewis bases and donor solvents (e.g., THF), and the naphthalene exchange reaction for another arene via $Cr(CO)_3$ fragment transfer proceeds at low temperature. The results with related substrates are summarized in Table I.



2

3

4

Table I. Diasteroselective Complexation of **2** with (Naphthalene)$Cr(CO)_3$

entry	R^1	R^2	X	ratio of 3:4	yield (%)
1	Me	Et	CH_2CH_2	89:11	85
2	Me	*i*-Pr	CH_2CH_2	96:4	89
3	Me	$CH{=}CH(Me)^a$	CH_2CH_2	92:8	73
4	Me	$C(Me){=}CH(Me)^a$	CH_2CH_2	98:2	85
5	Et	Et	CH_2CH_2	94:6	95
6	*i*-Pr	Et	CH_2CH_2	94:6	95
7	*i*-Pr	$CH{=}CH(Me)^a$	CH_2CH_2	94:6	80
8	Me	Et	$CH_2CH_2CH_2$	65:35	90
9	Me	Et	$CH_2C(Me)_2CH_2$	57:43	60

[a] E double bond geometry.

The diastereoselectivity of this ligand exchange reaction with (naphthalene)$Cr(CO)_3$ increased with increasing steric bulkiness of both alkyl groups (R^1 and R^2). The ethylene acetal group at the benzylic position is important for the high selectivity as shown in the following results. In contrast to the ethylene acetal (entries 1–7), the corresponding propylene acetal and 2,2-dimethylpropylene acetal derivatives afforded no diastereoselectivity (entries 8 and 9). 5-(*o*-Methoxyphenyl)-3-pentanol with no acetal function at the benzylic position was reacted with (naphthalene)$Cr(CO)_3$ to give the corresponding diastereomeric chromium complexes in a ratio of 61:39. However, the *gem*-dimethyl group at the benzylic position, 5-methyl-5-(*o*-methoxyphenyl)-3-hexanol, gave predominantly the corresponding S^*,R^*-chromium complex in a ratio of 92:8. It may be concluded that a Thorpe–Ingold effect[10] is

---

[1] (a) Uemura, M.; Kobayashi, T.; Minami, T.; Hayashi, Y. *Tetrahedron Lett.* **1986**, *27*, 2479–2482. (b) Brocard, J.; Lebibi, J.; Pelinski, L.; Mahmoudi, M. *Ibid.* **1986**, *27*, 6325–6328.

[2] Uemura, M.; Kobayashi, T.; Isobe, K.; Minami, T.; Hayashi, Y. *J. Org. Chem.* **1986**, *51*, 2859–2863.

[3] The symbol S^*,S^* represents an enantiomeric mixture of *S,S*- and *R,R*-chromium complexes. The first symbol indicates a stereochemistry of the complexed aromatic part, and the second one shows the configuration of the chiral center at the side chain.

[4] (a) Meyer, A.; Dabard, R. *J. Organomet. Chem.* **1972**, *36*, C38–42. (b) Besancon, J.; Tirouflet, J.; Card, A.; Dausauoy, Y. *Ibid.* **1973**, *59*, 267–279. (c) Solladie-Cavallo, A.; Suffert, J. *Tetrahedron Lett.* **1984**, *25*, 1897–1900. (d) Solladie-Cavallo, A.; Suffert, J. *Synthesis* **1985**, 659–662, and references cited therein.

[5] Although 8-methoxy-1-tetralone gave no arene chromium complex with $Cr(CO)_6$, the corresponding ethylene acetal derivative afforded the arene chromium complex in good yield: Uemura, M.; Isobe, K.; Hayashi, Y. *Chem. Lett.* **1985**, 91–94.

[6] Aldol reaction of the lithium enolate of tricarbonyl(*o*-methoxyacetophenone)chromium with propionaldehyde gave the diastereomeric mixture of tricarbonyl(3-hydroxy-1-*o*-(methoxyphenyl)-1-pentanone)chromium in a 3:2 ratio. Therefore, we have studied direct $Cr(CO)_3$ complexation in order to obtain high diastereoselectivity.

[7] All new compounds gave satisfactory analytical and spectroscopic data. The stereochemistry of S^*,R^*-complex **3** (R^1 = *i*-Pr, R^2 = Et, X = CH_2CH_2) and S^*,S^*-complex **7** (R^1 = *i*-Pr, R^2 = Me) was determined by X-ray crystallography.

[8] Gracey, D. E. F.; Jackson, W. R.; McMullen, C. H.; Thompson, N. *J. Chem. Soc.* **1969**, 1197–1203.

[9] Kündig, E. P.; Perret, C.; Spichinger, S.; Bernardienelli, G. *J. Organomet. Chem.* **1985**, *286*, 183–200.

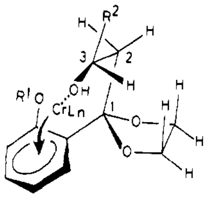
[10] (a) DeTar, D. F.; Luthra, N. P. *J. Am. Chem. Soc.* **1980**, *102*, 4505–4512. (b) Exon, C.; Magnus, P. *Ibid.* **1983**, *105*, 2477–2478. We are indebted to a referee for the useful suggestion that a Thorpe–Ingold effect may be operative for high diastereoselective chromium complexation.

0002-7863/87/1509-5277$01.50/0

Table II. Diastereoselective Complexation of **6** with (Naphthalene)$Cr(CO)_3$

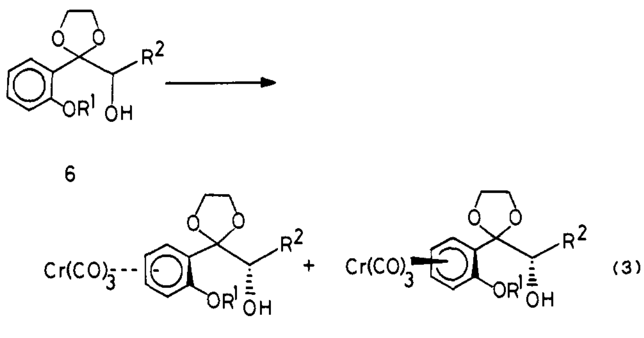
entry	R^1	R^2	ratio of **7**:**8**	yield (%)
1	Me	Me	85:15	80
2	Me	*n*-Bu	85:15	83
3	*i*-Pr	Me	92:8	88

operative for the high diastereoselective chromium complexation. The hydroxyl group of the side chain also plays an important function for high selectivity. Thus, the corresponding acetate of **2** (R^1 = Me, R^2 = Et, X = CH_2CH_2) gave a diastereomeric mixture in a ratio of 65:35. The appearance of high diastereoselectivity on the ligand exchange reaction can be explained by $Cr(CO)_3$ complexation via an intermediate **5**, in which the ethylene acetal (or *gem*-dimethyl) group is moved away from the *o*-alkoxyl group by rotation around the C(1)–C(Ar) bond due to steric effect, and the R^2 group is positioned to avoid severe steric interactions with the hydrogen atoms of ethylene acetal (or methyl) group.



5

We next studied diastereoselective chromium complexation of the compounds **6**[11] with hydroxyl groups at the C-2 position of the alkyl side chain. In contrast to the above results (Table I), S^*,S^*-chromium complexes **7**[7] were predominantly obtained in these cases under the same reaction conditions (eq 3). The intermediate for complexation of **6** may be similar with **1** in which steric interactions between the *o*-alkoxy group and the alkyl group of the side chain are diminished by the spacial arrangement of these groups (Table II).

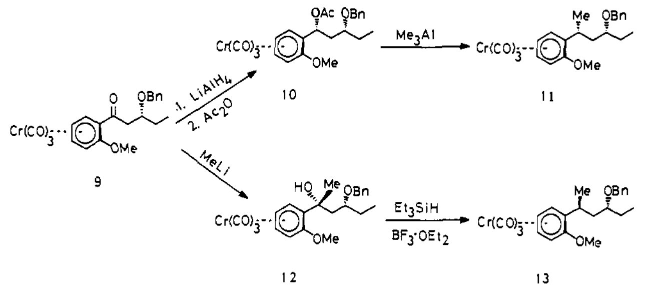


6

7

8

These chromium complexes prepared by the above ligand exchange reactions can undergo reactions in which control of the stereochemistry in the acyclic side chain is exhibited as follows. Protection of the hydroxyl group of the complex **3** (R^1 = Me, R^2 = Et, X = CH_2CH_2) by benzylation (BnBr/NaH/DMF/room temperature) and subsequent hydrolysis of the ethylene acetal (concentrated H_2SO_4/acetone/0 °C) gave an oily product **9** in 55% overall yield. Reduction of the carbonyl group of **9** with $LiAlH_4$ at –78 °C followed by acetylation afforded S^*,R^*,R^*-chromium complex **10** exclusively in 85% yield.[12] No trace of the corresponding epimeric complex at the benzylic position was detected. The treatment of **10** with Me_3Al in CH_2Cl_2 at –78 °C gave a single diastereomeric complex **11** as an oil in 50% yield. On the other hand, reaction of **9** with MeLi gave a single methylated complex **12** (mp 110 °C) which was converted to another



diastereomeric S^*,S^*,R^*-complex **13** (mp 94 °C) in 75% yield by ionic hydrogenolysis ($Et_3SiH/BF_3{\cdot}OEt_2/CH_2Cl_2$/–78 to 0 °C) without the formation of the epimeric syn isomer **11**. These syn and anti chromium complexes, **11** and **13**, are useful compounds for further acyclic stereocontrol, since the $Cr(CO)_3$-complexed anisole rings could be transformed into substituted cyclohexenone derivatives via stereo- and regioselective nucleophilic addition and subsequent protonation as developed by Semmelhack.[13]

Acknowledgment. We thank Dr. K. Hirotsu, Osaka City University, for X-ray crystallography of compounds **3** (R^1 = *i*-Pr, R^2 = Et, X = CH_2CH_2) and **7** (R^1 = *i*-Pr, R^2 = Me).

---

[11] These compounds **6** were prepared by the following literature method: Cuvigny, T.; Larcheveque, M.; Normant, H. *Synthesis* **1978**, 857–858.

[12] The reduction of complex **9** with $Zn(BH_4)_2$ or $NaBH_4$ gave one diastereomeric chromium complex **10**.

[13] Semmelhack, M. F.; Clark, G. R.; Garcia, J. L.; Harrison, J. J.; Thebtaranonth, Y.; Wulff, W.; Yamashita, A. *Tetrahedron* **1981**, *37*, 3957–3965, and references cited therein.

Solid-State NMR Evidence for the Formation of Carbocations from Propene in Acidic Zeolite-Y

Minoo Zardkoohi, James F. Haw,* and Jack H. Lunsford*

Department of Chemistry, Texas A&M University
College Station, Texas 77843

Received February 5, 1987

Zeolites in the hydrogen form are widely used for such acid-catalyzed reactions as the cracking of alkanes, alkene isomerization, alkylation, and the conversion of methanol to hydrocarbons.[1] Although much of this chemistry can be explained via mechanisms involving carbocations, spectroscopic evidence for these intermediates in zeolites is limited. Earlier work by Leftin and Hall[2–4] on amorphous silica–alumina catalysts demonstrated, by using UV spectroscopy, that carbocations were formed upon adsorption of 1,1-diphenylethylene or triphenylmethane. More recently Maciel[5] has reported the ^{13}C CP-MAS spectrum of the triphenylmethyl carbocation following the surface reaction of triphenylchloromethane with silica–alumina.

From NMR studies remarkable progress has been made in understanding the chemistry of carbocations in solution. The ^{13}C spectra of carbenium ion centers are significantly deshielded; i.e., they are characterized by large positive chemical shifts. Both structural and dynamic information can be obtained from the magnitude of the chemical shifts. Similar information can be derived from NMR spectra of carbocations in the solid state, as demonstrated by the work of Myhre and Yannoni,[6] who formed *sec*-butyl and *tert*-butyl cations by codepositing 2-chlorobutane and antimony pentafluoride at low temperatures. The spectra indicate the presence of a dynamic *sec*-butyl cation at temperatures as low as –190 °C.

---

[1] Pines, H. *The Chemistry of Catalytic Hydrocarbon Conversion*; Academic Press: New York, 1981.

[2] Leftin, H. P.; Hall, W. K. *J. Phys. Chem.* **1962**, *66*, 1457.

[3] Leftin, H. P.; Hall, W. K. *Actes Congr. Int. Catal. 2nd* **1960**, *1*, 1353.

[4] Leftin, H. P.; Hall, W. K. *J. Catal.* **1967**, *8*, 394.

[5] Maciel, G. E. In *Heterogeneous Catalysis*; Shapiro, B. L., Ed.; Texas A&M University Press: College Station, 1984; pp 349–381.

[6] Yannoni, C. S.; Myhre, P. C. *J. Am. Chem. Soc.* **1981**, *103*, 230.

0002-7863/87/1509-5278$01.50/0