7.36 (s, 1 H); IR ($CHCl_3$) 1630 (C=N), 1580, 1480 (aromatic C=C), 1370 (aromatic C—N), 830 $cm^{-1}$ (aromatic CH); UV (EtOH) 268 nm ($\epsilon$ 7600); mass spectrum, $m/e$ (relative intensity) 228 (82), 226 (100), 213 (57), 211 (61), 186 (46), 184 (71).

**β-(Dimethylamino)vinyl *p*-Bromophenyl Ketone.** A solution of sodium methoxide in methanol was prepared by the addition of 1.5 g (0.065 mol) of sodium metal to 100 mL of absolute methanol. After all of the sodium had reacted, the solution was cooled to room temperature and 10.0 g (0.050 mol) of *p*-bromoacetophenone was added in one portion. After the solution had stirred for several minutes, 10.6 g (0.065 mol) of [3-(dimethylamino)-2-azaprop-2-en-1-ylidene]dimethylammonium chloride was added and the resulting mixture was refluxed with stirring overnight. The reaction mixture was cooled to room temperature and the solvent was removed in vacuo. The residue was taken up in chloroform (100 mL) and extracted twice with an aqueous solution of sodium bicarbonate (30-mL portions). The resulting chloroform phase was dried over anhydrous sodium sulfate, filtered, and concentrated in vacuo to afford 13.5 g of a dark brown solid. This material was stirred with 50 mL of a 10% carbon tetrachloride/hexane mixture and filtered to give 9.4 g (74% yield) of the enamino ketone as a light brown solid: mp 75–76 °C; NMR ($CDCl_3$) $\delta$ 2.98 (s, 6 H), 5.68 (d, $J$ = 13 Hz, 1 H), 7.45 (d, $J$ = 9 Hz, 2 H), 7.72 (d, $J$ = 9 Hz, 2 H), 7.72 (d, $J$ = 13 Hz, 1 H); IR ($CHCl_3$) 1640 (C=O), 1575 (C=C), 1535, 1420 (aromatic C=C), 1353 (C—N), 900 $cm^{-1}$ (aromatic CH); UV (EtOH) 343 ($\epsilon$ 21 900), 248 nm ($\epsilon$ 13 000). Anal. Calcd for $BrC_{11}H_{12}NO$: C, 51.99; H, 4.76; N, 5.51. Found: C, 51.61; H, 4.76; N, 5.44; mass spectrum, $m/e$ (relative intensity) 255 (28), 254 (8), 253 (39), 252 (4), 240 (6), 239 (10), 238 (99), 237 (12), 236 (100).

**N′-(*p*-Nitrobenzoyl)-*N*,*N*-dimethylformamidine.** A solution of sodium isopropoxide in isopropyl alcohol was prepared by the addition of 1.4 g (0.060 mol) of sodium metal to 100 mL of absolute isopropyl alcohol. After all of the sodium had reacted, the solution was cooled to room temperature and 8.3 g (0.050 mol) of *p*-nitrobenzamide was added in one portion. After the solution had stirred for several minutes, 10.6 g (0.065 mol) of [3-(dimethylamino)-2-azaprop-2-en-1-ylidene]dimethylammonium chloride was added and the resulting mixture was refluxed with stirring overnight. The reaction mixture was cooled to room temperature and the solvent was removed in vacuo. The residue was taken up in chloroform (100 mL) and extracted twice with an aqueous solution of sodium bicarbonate (30-mL portions). The resulting chloroform phase was dried over anhydrous sodium sulfate, filtered, and concentrated in vacuo to afford 13.1 g of a yellow solid. This material was recrystallized from 10:1 carbon tetrachloride–chloroform to give 8.9 g (81% yield) of a white solid: mp 132–135 °C (lit.[9] mp 141–143 °C); NMR ($CDCl_3$) $\delta$ 3.20 (s, 6 H), 8.12 (d, $J$ = 9 Hz, 2 H), 8.34 (d, $J$ = 9 Hz, 2 H), 8.31 (s, 1 H); IR ($CHCl_3$) 1630 (C=O), 1600 (C=N), 1580 (aromatic $NO_2$), 1470 (aromatic C=C), 1330 (aromatic $NO_2$), 830 $cm^{-1}$ (aromatic CH).

**Acknowledgment.** This research was supported in part by grants from the Research Corporation and the University of Central Florida, Division of Sponsored Research. We also thank the Foods Division of Coca-Cola Company, Plymouth, FL, for the gift of the mass spectrometer and Mr. Garry Kiefer of L.S.U. for obtaining the combustion analyses and some of the mass spectra. We would also like to thank Dr. John P. Idoux for helpful discussions during the course of this work.

**Registry No.** 1, 20353-93-9; cyanuric chloride, 108-77-0; *N*,*N*-dimethylformamide, 68-12-2; *p*-toluidine, 106-49-0; *o*-toluidine, 95-53-4; *p*-nitroaniline, 100-01-6; *p*-bromoaniline, 106-40-1; *o*-phenylenediamine, 95-54-5; *N*,*N*-dimethyl-*N*′-*p*-methylphenylformamidine, 7549-96-4; *N*,*N*-dimethyl-*N*′-*o*-methylphenylformamidine, 10278-71-4; *N*,*N*-dimethyl-*N*′-*p*-nitrophenylformamidine, 1205-59-0; *N*,*N*-dimethyl-*N*′-*p*-bromophenylformamidine, 13181-50-5; benzimidazole, 51-17-2; acetophenone, 98-86-2; *p*-nitroacetophenone, 100-19-6; *p*-bromoacetophenone, 99-90-1; *p*-methoxyacetophenone, 100-06-1; β-(dimethylamino)vinyl phenyl ketone, 1201-93-0; β-(dimethylamino)vinyl *p*-nitrophenyl ketone, 68760-11-2; β-(dimethylamino)-vinyl *p*-bromophenyl ketone, 73387-60-7; β-(dimethylamino)vinyl *p*-methoxyphenyl ketone, 18096-70-3; benzamide, 55-21-0; *p*-nitrobenzamide, 619-80-7; nicotinamide, 98-92-0; *N*′-benzoyl-*N*,*N*-dimethylformamidine, 41876-75-9; *N*′-(*p*-nitrobenzoyl)-*N*,*N*-dimethylformamidine, 65675-91-4; *N*′-nicotinoyl-*N*,*N*-dimethylformamidine, 71565-88-3.

# *Communications*

## Effect of Substituents on the Structure and Catalytic Activity of Arene Chromium Tricarbonyls

*Summary:* Heteroatom substituents induce a strong perturbation in the six-electron ligand–metal bond of arene $Cr(CO)_3$ compounds, which enhance their catalytic activity.

*Sir:* The use of chromium tricarbonyl compounds as catalysts for the regioselective 1,4-hydrogenation of dienes to monoenes is of special interest in view of the high cis stereospecificity of products attained in the reaction.[1] The simple monoarenes thermally catalyze the reaction at high pressures (50 atm) and high temperatures (150–175 °C).[2] It has been reported that electron-withdrawing substituents in the arene accelerated the reaction while electron-donating group ($CH_3$) inhibited, to a large extent, the efficiency of the catalyst.[3] It has been suggested that the true catalytic species in a coordinating solvent (L) was $L_3Cr(CO)_3$.[4] These properties were related to the changes in the total metal–arene bond strength. However, this simple scheme does not account for the new substituent effects shown here that allow catalytic hydrogenation under surprisingly mild conditions (70 °C).[5]

All the complexes were prepared by using slight modifications of Pauson's procedure[6] and the catalytic experiments were carried out in a Burton Corblin A.F.P. 305 magnet drive autoclave.

The hydrogenation of methyl sorbate into methyl 3-hexenoate in THF has been studied as a test reaction. Some characteristic results are listed in Table I. The following comments can be made. (1) The catalytic efficiency of arene complexes bearing heterosubstituents is

(1) For a review, see M. Cais and D. Fraenkel, *N.Y. Acad. Sci.*, in press.
(2) M. Cais, E. N. Frankel, and A. Rejoan, *Tetrahedron Lett.*, 1919 (1968).
(3) E. N. Frankel and R. O. Butterfield, *J. Org. Chem.*, 34, 3930 (1969).
(4) Y. Eden, O. Fraenkel, M. Cais, and E. A. Halevi, *Isr. J. Chem.*, 15, 223 (1976).
(5) The possibility of decreasing the reaction temperature in these systems is important in order to favor cheap, clean, and selective reactions (G. Yagupsky and M. Cais, *Inorg. Chim. Acta*, 12, 127 (1975)). Consequently, pressure conditions may also be diminished (e.g., 70 °C and 6 atm).
(6) C. A. Mahaffy and P. L. Pauson, *Inorg. Synth.*, 19, 154 (1979).

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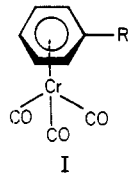
Table I. Hydrogenation of Methyl Sorbate Catalyzed by Complexes I[a]



I

| compd | R | other substituents | % methyl 3-hexenoate at 70 °C | 80 °C | 90 °C | 100 °C | 120 °C |
|---|---|---|---|---|---|---|---|
| 1 | $CO_2CH_3$ | | | | | 0 | 3 |
| 2 | $OCH_3$ | | | | | 0 | 100 |
| 3 | $N(C_2H_5)_2$ | | | | | 0 | 100 |
| 4 | $OCH_3$ | 2-$OCH_3$ | | | 0 | 100 | 100 |
| 5 | $OCH_3$ | 3-$OCH_3$ | | | 0 | 100 | 100 |
| 6 | $OCH_3$ | 4-$OCH_3$ | | | | 0 | 100 |
| 7 | $OCH_3$ | 2,6-$OCH_3$ | 0 | 100 | 100 | 100 | 100 |
| 8 | $CO_2CH_3$ | 4-$OCH_3$ | | | 0 | 100 | 100 |
| 9 | $CO_2CH_3$ | 2-$OCH_3$ | | | | 42 | 100 |
| 10 | $NH_2$ | 2-$OCH_3$ | | | | 82 | 100 |
| 11 | $CO_2CH_3$ | 3,4,5-$(OCH_3)$ | 70 | 100 | 100 | 100 | 100 |

[a] In order to permit direct comparisons, reaction time (5 h) and hydrogen pressure (60 atm) were kept identical over this range of experiments carried out in THF using $2 \times 10^{-2}$ M catalyst.

Table II. Cr-C(ring) Distances (Å)

| | $[(C_2H_5)_2N(C_6H_5)]$-$Cr(CO)_3$ | $[1,2,6\text{-}(OCH_3)_3(C_6H_3)]$-$Cr(CO)_3$ |
|---|---|---|
| Cr-C(1) | 2.369 (2) | 2.270 (2) |
| Cr-C(2) | 2.243 (2) | 2.288 (2) |
| Cr-C'(2) | 2.245 (2) | 2.284 (2) |
| Cr-C(3) | 2.189 (2) | 2.235 (2) |
| Cr-C'(3) | 2.185 (2) | 2.244 (2) |
| Cr-C(4) | 2.208 (2) | 2.193 (2) |

clearly demonstrated (compare for example with ref 1). (2) Among the simple monosubstituted arene complexes, compounds **2** and **3** are to our knowledge, the most efficient 1,4-hydrogenation catalysts reported so far. (3) Compounds **4**, **5**, **7**, **8**, and **11** exhibit excellent activity at 100 °C and even at 90 °C (for **4**, **5**, **7**, **11**), which supports the idea that the presence of several substituents on the arene ring enhances the ease of liberation of the six-electron ligand. (4) The symmetrically disubstituted compounds **4–6** show a decrease in activity when going from ortho to meta to para positions, while the unsymmetrically substituted structures **8–10** are still reasonably active at 100 °C. (5) Among the studied compounds, 1,2,3-trimethoxybenzene–$Cr(CO)_3$ (**7**) and methyl 3,4,5-trimethoxy benzoate–$Cr(CO)_3$ (**11**) are still active at 80 °C and even at 70 °C in the last instance.

X-ray structural analysis may be a useful tool for prediction of catalytic effects of organometallic molecules. Particularly, disparity in Cr–C(ring) distances has been related to the facility of labilization of the arene in condensed polyaromatic complexes.[7] Therefore it was of interest to carry out an X-ray molecular structure of mono- or polyamino- or methoxy-substituted arene–$Cr(CO)_3$ compounds in order to detect possible structural particularities so far ignored in this monarene series.

The most salient aspect of the molecular structure of both $[(C_2H_5)_2N(C_6H_5)]Cr(CO)_3$ (**3**) and 1,2,3-trimethoxybenzene–$Cr(CO)_3$ (**7**) is the noticeable disparity in the

(7) M. Cais, D. Fraenkel, and K. Weidenbaum, *Coord. Chem. Rev.*, **16**, 27 (1975).

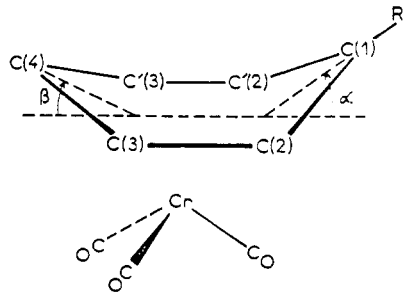



**Figure 1.** Arene ring out of plane deformation: **3**, $\alpha = 7.4°$, $\beta = 2.7°$, R = $NEt_2$; **7**, $\alpha = -4.1°$, $\beta = -1.0°$, R = 1-OMe.

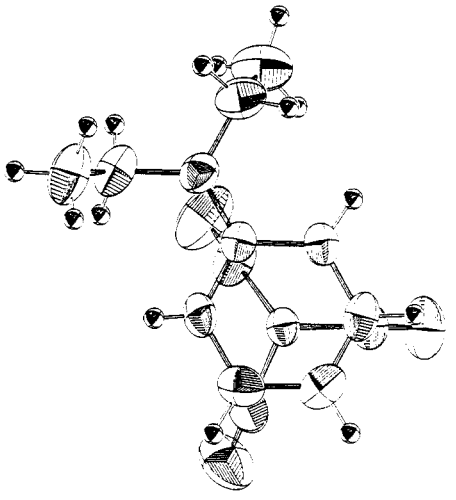


**Figure 2.** ORTEP view of compound **3**.

Cr–C(ring) distance as listed in Table II. On the basis of the structural analysis of the arene–metal moieties which adopt in both cases a quasi $C_s$ point group symmetry, one may interpret this disparity as the result of two main factors: (1) an out-of-plane deformation of the arene as shown in Figure 1 (The C(1) and C(4) ring carbons are significantly situated out of the mean plane of the four other ones–pointing toward the chromium atom for compound **7** and in the opposite direction for the other example, **3**. The methoxy derivative **7** shows a weaker bend than **3**);[8] (2) a displacement of the $Cr(CO)_3$ moiety with respect to the arene ring. (Thus, the chromium atom projection onto the C(2),C'(2), C(3),C'(3) mean plane is shifted from the barycentric projection of the six arene carbon atoms toward C(4). The exact values of the displacement from the center are 0.079 (2) Å for **3** and 0.076 (2) Å for **7**.)

The structural features do not result from steric interactions between the metal atom and the amino or methoxy substituents. In both cases, the distances of the chromium and substituent atoms are larger than 3.3 Å.. Furthermore,

(8) Such a few degrees buckling of an arene ring means, indeed, a weak energetic difference with respect to the planar benzene (H. Wynberg, W. C. Nieuwport, and H. T. Jonkman, *Tetrahedron Lett.*, 4623 (1973)). Moreover similar bends have been reported in *N*-paracyclophane series[9] and X-ray structures of some $NO_2$ derivatives of aniline and phenetole[10] show also a boat shape ring with the ipso and para carbon atoms, with respect to the $NH_2$ or $OC_2H_5$ substituents being removed from the mean plane of the ring. It is interesting to note that a similarity between the electronic properties of $Cr(CO)_3$ and $NO_2$ has been reported.[11]

(9) See, for example, N. L. Allinger, J. T. Sprage, and T. Liljefors, *J. Am. Chem. Soc.*, **96**, 5100 (1974), and references therein.

(10) (a) C. Dickinson,J. M. Stewart, and J. R. Holden, *Acta Crystallogr.*, **21**, 663 (1966); (b) C. Grammacioli, R. Destro, and M. Simonetta, *Acta Crystallogr., Sect. B*,. **24**, 129 (1967); (c) J. R. Holden, C. Dickinson, C. M. Bock, *J. Phys. Chem.*, **76**, 3597 (1972).

(11) B. Nicholls and M. C. Whiting, *J. Chem. Sco.*, 551 (1959).

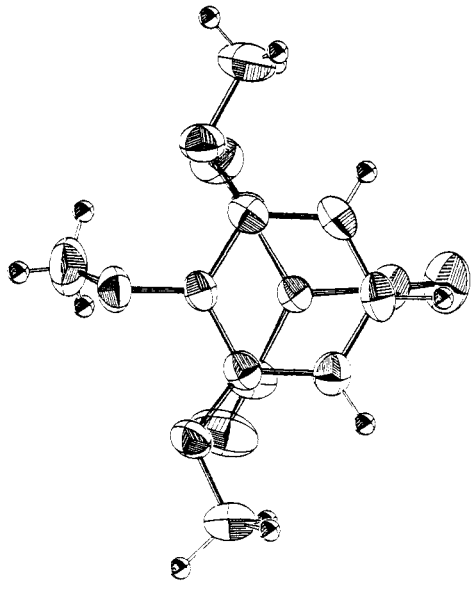


**Figure 3.** ORTEP view of compound 7.

these compounds exhibit strong conjugative effects of the adjacent group(s) with the arene ring; for example, in the $N(Et)_2$ case, the N–C(1) distance (1.357 (3) Å), characteristic of a partial double bond, is associated with a planar conformation of the nitrogen atom. It has been previously shown both from experimental[12] and theoretical[13] studies that the nitrogen atom of aniline is pyramidal. The structural feature of **3** and **7** (see Figures 2 and 3) may be related to the strong effect of the substituents attached to the arene. Therefore, the chromium atom displacement may follow the drift of the electron density from the barycenter of the ring.

The above data point out that, for strongly perturbing groups possessing a lone pair and situated in a position $\alpha$ to the arene, the structural alteration of the Cr–ring bond brings about the facile generation of the catalytic species. The previous explanations of the catalytic efficiency of monoarenes–$Cr(CO)_3$ based on the total strength of the bond must then be completed by symmetry considerations. It is clear that judiciously selected antagonist substituents might allow access to new reactive catalysts. We are now exploring the limits of this approach and looking for the extension of these ideas on new catalytic systems.[14]

**Acknowledgment.** We thank Professor M. Cais and Dr. D. Thompson for helpful discussions.

**Registry No.** 1, 12125-87-0; 2, 12116-44-8; 3, 12242-29-4; 4, 12176-27-1; 5, 12176-28-2; 6, 12176-26-0; 7, 12193-72-5; 8, 12241-72-4; 9, 12182-02-4; 10, 57629-45-5; 11, 63168-35-4; methyl sorbate, 689-89-4; methyl *cis*-3-hexenoate, 13894-62-7.

(12) D. G. Lister and J. K. Tyler, *Chem. Commun.*, 152 (1966).
(13) W. J. Here, L. Radom, and J. A. Pople, *J. Am. Chem. Soc.*, **94**, 1496 (1972).
(14) Data collection and refinement of structure from the X-ray analysis are given below. **3**: monoclinic; $a$ = 9.562 (3), $b$ = 10.307 (3), $c$ = 13.785 (5) Å; $\beta$ = 96.34 (4)°; $D_c$ = 1.40 mg cm$^{-3}$; $Z$ = 4; space group $P2_1/n$. **7**: monoclinic; $a$ = 7.370 (2), $b$ = 24.731 (5), $c$ = 6.968 (2) Å; $\beta$ = 103.63 (2)°; $D_c$ = 1.51 mg cm$^{-3}$; $Z$ = 4; space group $P2_1/c$. Three-dimensional X-ray diffraction data were collected on a computer-controlled four-circle Nonius CAD 4 diffractometer using graphite-monochromated Mo K$\alpha$ radiation and $\omega$–$2\theta$ scans. Scan angle (degrees) is given by $S$ = 1.00 + 0.35 tan $\theta$ for both compounds. Counter aperture (mm) is calculated from $d$ = 2.0 + 0.5 tan $\theta$ for **3** and $d$ = 2.5 + 0.4 tan $\theta$ for **7**. For both structures, atoms were located through direct method (MULTAN) and standard difference Fourier techniques and the resulting structural parameters have been refined to convergence (**3**, $R$ = 0.064, $R_w$ = 0.050, for 2757 independent reflections having 28° > $\theta$ > 1°; **7**, $R$ = 0.055, $R_w$ = 0.054, for 3301 independent reflections having 30° > $\theta$ > 1°), using unit-weighted full-matrix least-squares techniques with anisotropic thermal parameters for all nonhydrogen atoms.

(15) (a) Laboratoire de Chimie des Organométalliques. (b) Laboratoire de Cristallochimie.

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## Synthesis of Methyl Peracetyl α-Hikosaminide, the Undecose Portion of the Nucleoside Antibiotic Hikizimycin[1]

*Summary:* A convergent synthesis of the fully protected derivative **2** of hikosamine, the undecose unit of the nucleoside antibiotic hikizimycin, is described.

*Sir:* The nucleoside antibiotic hikizimycin (**1**), isolated from *Streptomyces longissimus* and *Streptomyces A-5*,[2,3] is one member of a rare class of naturally occurring compounds with a long-chain complex carbohydrate as a key structural feature.[4-8] Hikizimycin (or anthelmycin) is a powerful anthelmintic agent[2] and has recently been shown to inhibit protein synthesis by preventing the peptide bond-forming reaction.[9] Other nucleoside antibiotics containing long-chain carbohydrate units are tunicamycin,[10] which is a powerful glycosylation inhibitor,[11] and sinefungin,[12,13] which has both antifungal and antiviral activity.[12-16] The undecose portion of hikizimycin is re-

(1) A portion of this research was presented at the 11th Central Regional Meeting of the American Chemical Society, Columbus, OH, May 1979; ORG-8. A systematic name for hikizimycin (anthelmycin, **1**) is 1-[6-*O*-(3-amino-3-deoxy-β-D-glucopyranosyl)-4-amino-4-deoxy-β-D-*glycero*-D-*galacto*-D-*gluco*-undecopyranosyl]cytosine. A systematic name for methyl peracetyl-α-hikosaminide (**2**) is methyl 4-acetamido-2,3,6,7,8,9,10,11-octa-*O*-acetyl-4-deoxy-α-D-*glycero*-D-*galacto*-D-*gluco*-undecopyranoside.
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