Journal of Organometallic Chemistry, 470 (1994) C4–C7

Preliminary Communication

Direct synthesis of (η^6-arene)-tricarbonylchromium complexes by arene displacement from tricarbonyl(η^5-1-methylpyrrole)chromium(0)

Andrea Goti

Centro di Studio sulla Chimica e la Struttura dei Composti Eterociclici e loro Applicazioni, C.N.R., Dipartimento di Chimica Organica, Università di Firenze, via G. Capponi 9, I-50121 Firenze (Italy)

Martin F. Semmelhack

Department of Chemistry, Princeton University, Princeton, NJ 08544 (USA)

(Received October 8, 1993)

Abstract

Arene displacement from the title complex occurs under unprecedented mild conditions in neutral media to afford (η^6-arene)tricarbonylchromium complexes. The process is most effective with heteroaromatic compounds: the first synthesis of a tricarbonyl(η^6-quinoline)chromium complex and the diastereoselective preparation of a (η^6-indole) complex derived from L-tryptophan are reported as representative examples.

Key words: Chromium; Arene; Pyrrole; Quinoline; Indole, Diastereoselectivity

(π-Arene)tricarbonylchromium(0) derivatives are key intermediates in a number of synthetic pathways [1]. The main goals for efficient application of synthetic strategies involving the use of arenechromium complexes in organic chemistry are: (i) to supply new types of complexed arene and; (ii) to obtain a single diastereoisomeric product in the complexation step of substituted aromatic compounds containing pendant stereogenic centres [2,3]. The latter would be more easily accomplished if one could prepare the desired arene complex under mild reaction conditions. Unfortunately, the complexation of arenes with standard reagents such as chromium hexacarbonyl requires harsh conditions, so that very little diastereoselectivity is usually exhibited in the complexation of simple aromatic systems, especially those with stereogenic centre(s) located far from the aromatic ring [3,4]. The availability of new reagents able to transfer the tricarbonylchromium group to aromatic systems at low temperature is therefore an important goal in organic synthesis [5]. We report here the use of tricarbonyl(η^5-1-methylpyrrole)chromium(0) (**1**) as an effective tricarbonylchromium complexing agent for heteroarenes under unprecedented mild conditions.

The synthesis of complex **1** had already been reported by Öfele and Dotzauer [6]. We employed a slight modification of the reported procedure, using ethyl acetate as polar solvent to dissolve the complex, which gave best yields in our hands [7*]. The observation that in donor solvents, either of the σ (tetrahydrofuran, acetone) or the π type (benzene), a rapid ligand exchange equilibrium involving **1** is established, prompted us to test the compound as a complexing reagent towards a wide range of structurally differentiated aromatic compounds. The reactions were performed mainly at room temperature, since an increase in the reaction temperature typically caused partial decomposition of the reagent **1**. The solvent of choice was ethyl acetate, since it does not promote exchange reactions and **1** dissolve in it to a fair extent. Dichloromethane was also used, but it caused the reaction rate to diminish slightly, possibly due to the lower solubility of **1** [8*].

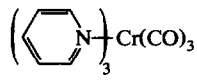
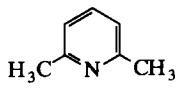
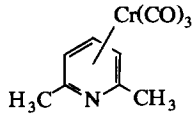
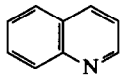
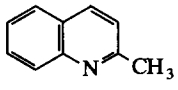
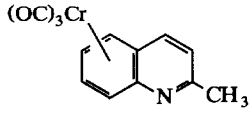
The results in the benzene series, although synthetically of minor importance, confirmed the tendency of **1** to give an arene replacement under these conditions. Indeed, by reaction of a ten-fold excess of toluene with respect to **1**, the toluene complex **3** (eqn. (1)) was obtained in moderate yield in only 1 h. The yield could not be increased by longer reaction times and is quite comparable to those reported for the same complex using $[Cr(CO)_6]$ with no catalyst added [9], however related benzene complexes are produced much more efficiently in the presence of "catalysts" such as THF [10], or by using different chromium carbonyls, *e.g.* $[(CH_3CN)_3Cr(CO)_3]$ [11] and $[(NH_3)_3Cr(CO)_3]$ [12]. Benzene derivatives which are more difficult to pre-

Correspondence to: Dr. A. Goti.

* Reference number with an asterisk indicates a note in the list of references.

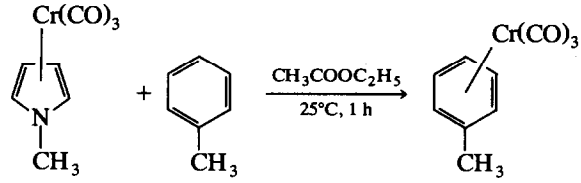
0022-328X/94/$7.00
SSDI 0022-328X(93)24378-I

TABLE 1. Synthesis of arene chromium complexes by reagent **1** in the pyridine and quinoline series [a]

Heteroarene (equiv.)	Product	Isolated yield (%)
 (5.4) **4**	 **5**	87 [b]
 (1) **6**	 **7**	15 [c]
 (0.67) **8**	decomposition products	
 (0.67) **9**	 **10**	67

[a] Reactions carried out in ethyl acetate at 25°C for 1 h, unless otherwise stated. [b] Reaction time: 30 min. [c] Reaction temperature: 60°C, reaction time: 3 h.

pare by standard chromium carbonyl complexing agents, such as iodobenzene and styrene [11,12], failed to give detectable amounts of product in the reaction with **1** at room temperature. Catalysts were not effective with reagent **1**; for example, only trace amounts of the desired complex from styrene were observed on adding THF to the reaction mixture, together with large quantities of decomposed material.

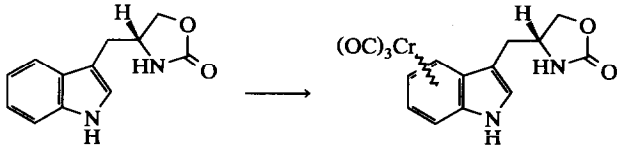


1 **2** **3**, 33% (1)

In contrast, the complexation reaction by reagent **1** with the three classes of nitrogen heteroaromatic compound which we have examined gave very promising results from a synthetic point of view. In Table 1 are the results of the complexation reaction of pyridine and quinoline derivatives, while Table 2 shows the results of the complexation of the optically active indole derivative **11**, derived from L-tryptophan.

With electron-deficient pyridine derivatives, **1** behaves in the usual way, affording a σ-complex with pyridine itself [13*] and a π-complex with 2,6-lutidine (**6**) [14]. The ligand exchange with pyridine (**4**) occurs

TABLE 2. Complexation of **11** by transfer of the tricarbonylchromium group



11 **12**

Entry	Complexing reagent	Reaction conditions	Isolated yield (%) (Diastereomeric ratio)
1	**1**	$CH_3COOC_2H_5$ 25°C, 1 h	91 (1:1)
2	**1**	$CH_3COOC_2H_5$ 0°C, 12 h	90 (1:1)
3	**1**	CH_2Cl_2 25°C, 2 h	85 (2.3:1)
4	**1**	CH_2Cl_2 0°C, 16 h	40 (2.3:1)
5 [a]	$[(CH_3CN)_3Cr(CO)_3]$	dioxane 100°C, 20 min	85 (1:1)
6	[(η^6-naphthalene)$Cr(CO)_3$]	Et_2O/THF (2 equiv.) 70°C, 12 h	94 (1:1)

[a] Ref. 18.

immediately, to give the useful complex **5** [15] in very good yield. 2,6-Lutidine (**6**) is much less reactive and its complexation requires higher temperatures, and the yield decreases. In both cases, the conditions employed are much milder and the procedures simpler than those usually needed for the preparation of **5** and **7** [15,16].

A more significant result has been achieved in the quinoline series, of which tricarbonylchromium complexes were unknown so far. The reaction with quinoline (**8**), either in ethyl acetate or dichloromethane, gave a rapid change of the solution from yellow to red, indicating that ligand displacement had occurred, but only decomposition products and no required complex could be recovered. However, quinaldine (**9**) gave smoothly the desired chromium complex **10** in good yield, even when using less than 1 equiv. of the starting quinoline derivative. As expected, the complexation occurred at the less electron deficient homocyclic ring, as attested by the much larger shielding of the protons of that ring [17*].

In view of the interest in indole tricarbonylchromium derivatives [18,19], the protected oxazolone **11**, obtained by reduction of L-tryptophan [20*] and successive condensation with phosgene [18], has been tested in the ligand exchange reaction. With this substrate diastereoselectivity of the formation of the new complex was studied simultaneously (Table 2).

Compound **11** gave the two possible diastereomeric complexes **12** in excellent yield in ethyl acetate at room temperature (entry 1), as a 1:1 mixture. Modifications of the reaction conditions, and comparison with the mildest and most diastereoselective complexation reagents available [2,3,5] (entries 5, 6) were made. At 0°C the complexation still took place, but much more slowly; and no improvement in selectivity was obtained (entry 2). The same reaction in dichloromethane led to a 70:30 mixture of the two diastereoisomers (entries 3, 4), either at 0°C or at room temperature. The low yield in entry 4 can be ascribed to the low stability of complex **1** in chlorinated solvents. Diastereomeric complexes **12** [21*] were inseparable by column chromatography; their ratio was evaluated by ^{1}H NMR spectra recorded on the crude reaction mixture with the added shift reagent, tris[3-(heptafluoropropylhydroxymethylene)-(+)-camphorato]ytterbium(III) [21*]. The diastereoselectivity of the complexation seems therefore to be solvent-dependent, but independent of temperature. The other complexing reagents, including tricarbonyl(η^6-naphthalene)-chromium(0) which is especially useful for diastereoselective complexation [2,3], gave high yields of product but without diastereoselectivity (entries 5, 6). The observed increase in diastereoselectivity is then considerable, taking account of the remoteness of the chiral centre and of the high flexibility of the system.

In conclusion, a reagent has been found that is able to afford (π-arene)tricarbonylchromium(0) complexes under extremely mild conditions. The reaction conditions employed, involving temperatures of 0 or 25°C, are to be compared with temperatures of around 150°C which are normally required for analogous arene displacement [22]. This result implies that haptotropic shifts in arene chromium complexes [22] are much easier in pyrrole than in benzene ligands.

This preliminary study has revealed the potential of **1** for applications to the synthesis of heteroarene chromium complexes and to the transfer of the tricarbonylchromium fragment to some classes of aromatic compound with a high degree of diastereoselectivity. The reagent deserves further studies to define fully its scope and limitations.

Acknowledgment

A.G. thanks the National Research Council (C.N.R.) Italy for a Postdoctoral fellowship.

References and notes

1 For a recent review on the subject, see: M.F. Semmelhack, in B.M. Trost and I. Fleming (eds.), *Comprehensive Organic Synthesis*, Vol. 4, Pergamon Press, New York, 1991.

2 A. Alexakis, P. Mangeney, I. Marek, F. Rose-Munch, E. Rose, A. Semra and F. Robert, *J. Am. Chem. Soc., 114* (1992) 8288; M. Uemura, T. Kobayashi, K. Isobe, T. Minami and Y. Hayashi, *J. Org. Chem., 51* (1986) 2859.

3 M. Uemura, T. Minami, K. Hirotsu and Y. Hayashi, *J. Org. Chem., 54* (1989) 469.

4 S.G. Davies, *J. Organomet. Chem., 400* (1990) 223; P.D. Baird, J. Blagg, S.G. Davies and K.H. Sutton, *Tetrahedron, 44* (1988) 171.

5 E.P. Kündig, C. Perret, S. Spichiger and G. Bernardinelli, *J. Organomet. Chem., 286* (1985) 183.

6 K. Öfele and E. Dotzauer, *J. Organomet. Chem., 30* (1971) 211.

7 Detailed procedure for the preparation of **1**: tris(acetonitrile)tricarbonylchromium(0) (1.4 g, 5.4 mmol) is put into an Ar-purged 100 ml Schlenk flask. Freshly distilled *N*-methylpyrrole (9 ml, 0.1 mol) is added and the mixture is heated at 60°C for 90 min. Concentration *in vacuo* of the orange-brown solution affords a yellow solid paste which is washed with hot (60°C) hexane (3×25 ml). The remaining solid is dissolved in hot (70°C) ethyl acetate and the solution filtered under Ar through a bed of Celite. The clear orange-brown solution is concentrated to *ca.* 30 ml and hexane (50 ml) is added. The supernatant liquid is removed via a cannula from the solid crystallized at 0°C, which is subsequently washed with hexane (2×10 ml) and dried *in vacuo*, to give pure **1** (0.8–1.1 g, 70–95% yield) as a deep yellow-orange solid. **CAUTION:** compound **1** is extremely pyrophoric and should be handled exclusively in a high purity dry-box. All the operations involving its preparation and use should be carried out in an O_2-free atmosphere and employing deoxygenated solvents. Complex **1** was unchanged after several months when stored as a solid in a dry-box.

8 Typical experimental procedure: 1 mmol of complex **1** is weighed into a well-dried, oxygen evacuated Schlenk flask (four cycles of vacuum-Ar purging) in a dry-box. Then a solution of the arene to be complexed (0.67–10 equiv.) in 20 ml of deoxygenated ethyl acetate is added in one portion via a cannula and the resulting mixture is stirred for 1 h at 25°. After concentration, the desired complex is purified by flash column chromatography under argon.

9 B. Nicholls and M.C. Whiting, *J. Chem. Soc.*, (1959) 551; M. Hudecek and S. Toma, *J. Organomet. Chem., 393* (1990) 115.

10 C.A.L. Mahaffy and P.L. Pauson, *Inorg. Synth., 19* (1979) 154.

11 G.R. Knox, D.G. Leppard, P.L. Pauson and W.E. Watts, *J. Organomet. Chem., 34* (1972) 347.

12 M.D. Rausch, G.A. Moser, E.J. Zaiko and A.R. Lipman, Jr., *J. Organomet. Chem., 23* (1970) 185.

13 [(η^6-pyridine)$Cr(CO)_3$] has been synthesized recently by desilylation of π-complexed hindered 2 or 2,6-trialkylsilyl-substituted pyridine derivatives: S.G. Davies and M.R. Shipton, *J. Chem. Soc., Perkin Trans. 1*, (1991) 501.

14 K.H. Pannell, B.L. Kalsotra and C. Parkanyi, *J. Heterocycl. Chem., 15* (1978) 1057.

15 D.E.F. Gracey, W.R. Jackson, W.B. Jennings and T.R.B. Mitchell, *J. Chem. Soc., (B)*, (1969) 1204; G. Carganico, P. Del Buttero, S. Maiorana and G. Riccardi, *J. Chem. Soc., Chem. Commun.*, (1978) 989.

16 H.-G. Biedermann, K. Öfele and J. Tajtelbaum, *Z. Naturforsch., 31b* (1976) 321.

17 ^{1}H NMR (C_6D_6) of **10**: δ 6.81 (d, J = 8.7 Hz, H at C4), 6.26 (d, J = 8.8 Hz, H at C3), 5.95 (d, J = 6.8 Hz, H at C5), 5.02 (d, J = 6.5 Hz, H at C8), 4.69 (dd, J = 7.0, 6.2 Hz, H at C6), 4.36 (dd, J = 6.4, 6.1 Hz, H at C7), 2.10 (s, CH_3).

18 M.F. Semmelhack, P. Knochel and T. Singleton, *Tetrahedron Lett., 34* (1993) 5051.

19 M.F. Semmelhack and H. Rhee, *Tetrahedron Lett., 34* (1993) 1395 and 1399; M.F. Semmelhack, W. Wulff and J.L. Garcia, *J. Organomet. Chem., 240* (1982) C5; P.J. Beswick, C.S. Greenwood, T.J. Mowlem, G. Neuchatel and D.A. Widdowson, *Tetrahedron, 44* (1988) 7325.

20 L-Tryptophan itself was found to be unreactive in the attempted complexation reaction towards either reagent **1** or other common complexation agents.

21 ^{1}H NMR (CD_3COCD_3) of **12**: δ 10.30 (br s, H at N1), 7.43 (s, H at C2), 6.84 and 6.72 (br s, NH), 6.67 and 6.64 (d, J = 6.6 Hz, H at C7), 6.43 and 6.41 (d, J = 6.4 Hz, H at C4), 5.61 and 5.58 (dd, J = 7.2, 6.5 Hz, H at C5), 5.27 and 5.24 (t, J = 6.4 Hz, H at C6), 4.48–4.30 (m, CH_2O), 4.16–4.06 (m, CHN), 3.06–2.90 (m, benzylic CH_2). In CD_2Cl_2 the overlapping signals of the two diastereoisomers at δ 6.33 (d, H at C7), 6.20 (d, H at C4), 5.51 (t, H at C5) are split by addition of 1 equiv. of [Yb(hfc)$_3$] to: δ 6.85 (d, H at C7), 6.48 (d, H at C4), 5.66 (t, H at C5) for the minor isomer, and δ 6.65 (d, H at C7), 6.40 (d, H at C4), 5.60 (t, H at C5) for the major isomer.

22 E.L. Muetterties, J.R. Bleeke and A.C. Sievert, *J. Organomet. Chem., 178* (1979) 197; T.G. Traylor and K.L. Stewart, *J. Am. Chem. Soc., 108* (1986) 6977.