Iron-Mediated Synthetic Routes to Unsymmetrically Substituted, Sterically Congested Benzophenones

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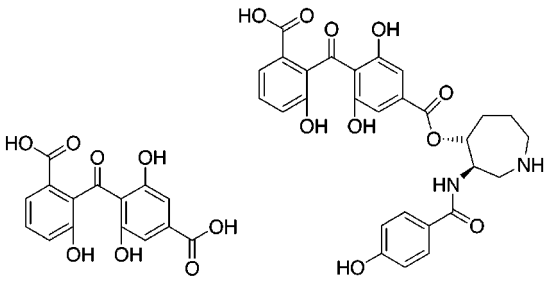
A new synthetic route to unsymmetrically substituted benzophenones, relying upon iron-mediated reactions in all of the key steps, is described. The key buiding block, η^6-2-chloro-carbomethoxybenzene-η^5-cyclopentadienyl iron hexafluorophosphate **(4),** is reacted with a variety of substituted phenols, providing diaryl ether complexes **(6)**. After hydrolysis of the ester functionalities, these complexes are subjected to Friedel−Crafts conditions. The efficiency of this intramolecular acylation reaction is very much dependent upon the substituents on the phenols. If these are appropriately chosen, xanthone complexes are isolated in fair to good yields. Regioselective ring-opening, using oxygen-nucleophiles, delivers substituted benzophenone complexes. After regioselective nucleophilic addition of cyanide ion, performed in the presence of DDQ, highly substituted benzophenones are isolated. To demonstrate the applicability of the new route, a formal synthesis of the benzophenone moiety of the protein kinase C inhibitor Balanol **(3)** is described.

Introduction

Upon coordination of an aromatic ring to a transition metal, many useful properties are conferred onto the ligand. Consequently, arene−metal complexes, particularly in the Cr, Mn, Fe, and Ru series, have received considerable attention as intermediates in alternative routes to functionalized aromatic molecules.[1] The most familiar within this type of π-coordinated molecules are the arene−chromium tricarbonyl complexes, which have become commonplace in modern organic synthesis.[2] The related cyclopentadienyl arene−iron complexes were discovered by Coffield et al. in 1957[3] and investigated in some detail by Nesmeyanov in the 1960s,[4,5] but their application in organic synthesis has remained largely unexplored.[6] This is surprising, because these cationic arene−iron complexes offer many attractive properties, the most prominent, perhaps, being an expressed umpolung of the arene ligand to become highly susceptible to nucleophilic attack. Furthermore, the low cost and toxicity of iron render its organometallic derivatives attractive for stoichiometric applications. We became interested in applying organoiron methodology for the synthesis of unsymmetrically substituted benzophenones not readily accessible via conventional routes.[7] In particular, we decided to investigate the synthetic potential of such an approach for the flexible synthesis of benzophenones related to **2**, a structural element found in the exceptionally potent protein kinase C inhibitor Balanol **(3)**[8] as well as in its regioisomer, the antifungal



2 **(-)-Balanol (3)**

ophiocordine.[9] This target presents a synthetically challenging, highly substituted, and severely crowded ben-

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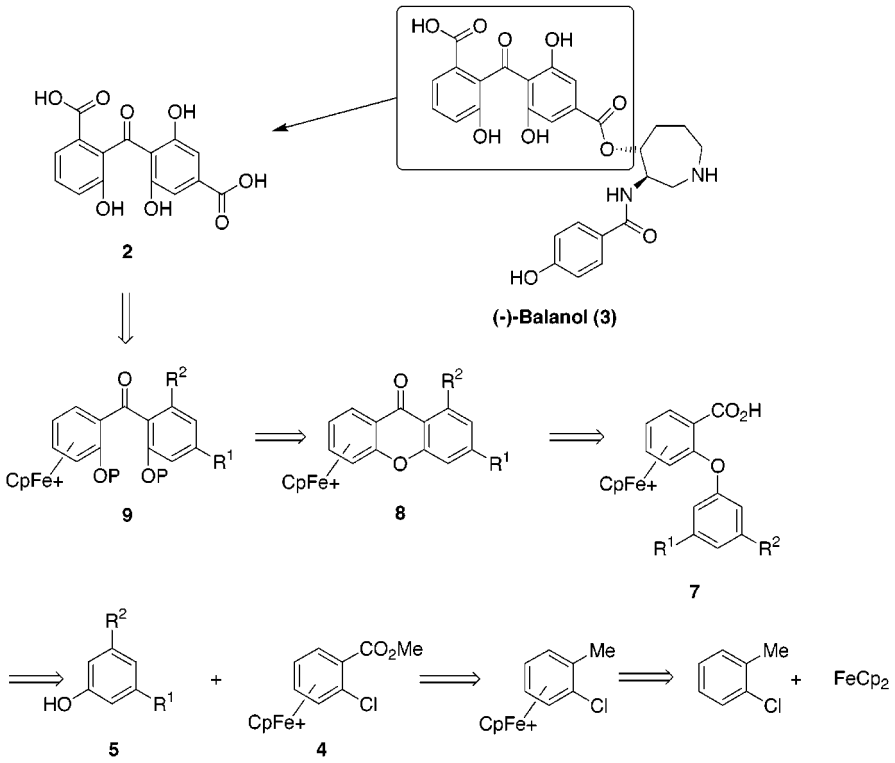
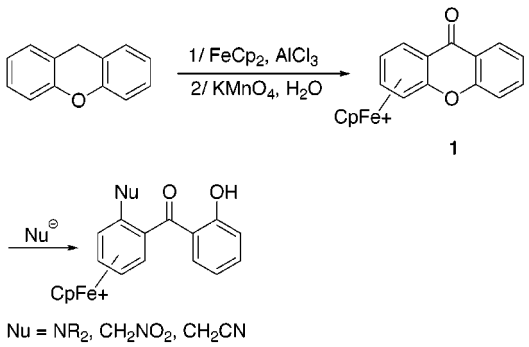


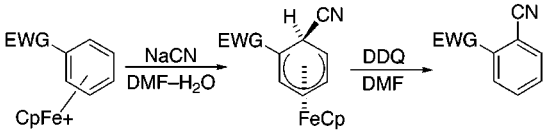
Figure 1. Retrosynthetic analysis of the benzophenone moiety **(2)** of Balanol **(3)**.

zophenone, which has been prepared previously only via fairly long sequences.[8c−i] We hypothesized that approaching the preparation of derivatives of **2** via ring-opening of a xanthone derivative might avoid some of the complications associated with steric hindrance in the formation of the carbonyl−arene bond using advanced intermediates. The key to our approach was the pioneering work by Sutherland et al. on the nucleophilic ring-opening of xanthone iron cyclopentadienyl hexafluorophosphate (**1**, Scheme 1).[10] Moreover, Sutherland et al. also discovered that certain electron-withdrawing substituents allowed regioselective addition of cyanide ion to arene−iron complexes, furnishing isolable, neutral cyclohexadienyl complexes which could be oxidatively demetalated (Scheme 2).[11] Sutherland's results inspired an obvious arene−iron mediated retrosynthetic analysis of benzophenones such as **2** (Figure 1). This strategy was intriguing to us, because it involved prototypical iron-mediated transformations at all of the key steps, and it also appeared to allow for significant flexibility; e.g., in the synthetic direction, complex **4** could be reacted with a variety of nucleophiles, such as phenols, thiophenols, or anilines. Furthermore, xanthone complex **8** (Figure 1) could potentially undergo regiocontrolled ring-opening

Scheme 1



Scheme 2



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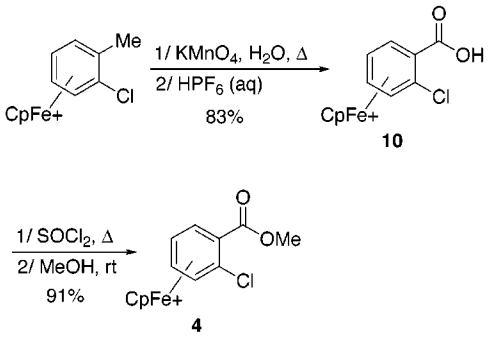
Scheme 3

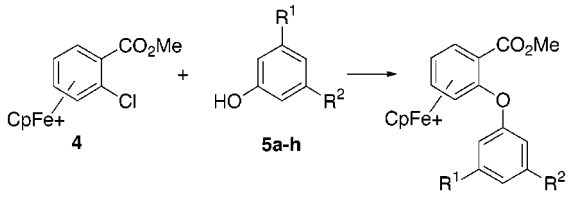


with various heteroatom or carbon nucleophiles, providing access to analogues carrying different substituents in the 2,2′,6,6′ positions. Following communications describing our initial progress toward preparation and ring-opening of the parent ring system as well as the application to the synthesis of the balanol appendage **2**,[12] the present paper describes full details of our studies regarding iron-mediated approaches to functionalized benzophenones.

Results and Discussion

Synthesis of (Xanthone)FeCp Complexes. The synthesis of the key building block **4** was accomplished by oxidizing the previously known η^6-2-chlorotoluene-η^5-cyclopentadienyl iron hexafluorophosphate[13] with aqueous potassium permanganate (Scheme 3). The benzoic acid complex **10** could be converted into the methyl ester **4**, in high overall yield, via reflux in thionyl chloride followed by reaction with excess methanol (Scheme 3). During our preliminary study concerning the preparation and ring-opening of the parent ring-system, we found it possible to substitute the chloride of **4** with phenoxide while avoiding transesterification. Also, the resulting diaryl ether complex, after saponification, took part in an intramolecular Friedel−Crafts reaction yielding the xanthone complex **1**. To approach the desired substitution pattern of the balanol appendage **2**, the hydroxyarene **5** (Figure 1) should carry a hydroxyl group (R^1) and a carboxylic acid equivalent (R^2). Two questions needed to be addressed: would the required 3,5-dihydroxy arene react cleanly as an oxygen nucleophile, and, could the regioselectivity of the intramolecular Friedel−Crafts reaction be controlled. In hydroxy arenes **5** where R^1 was a hydroxy group (Figure 1), the answer to the first question turned out to be dependent on the nature of the R^2 group. Thus, 3,5-dihydroxy arenes **5** wherein R^2 was hydrogen or an electron-withdrawing group (**5a**, **b**, **e**) reacted exclusively as oxygen nucleophiles, yielding diaryl ethers smoothly and in high yield (Table 1). On the other hand, electron-donating R^2 groups in **5** (R^2 = Me, *i*-Pr, or 1,3-dithian-2-yl) gave intractable mixtures of diaryl ether complexes and various carbon−carbon coupled products. However, after monoprotection of the problematic dihydroxy arenes, the diaryl ether complexes **6a**−**j** could be synthesized in useful yields (Tables 1). The methyl esters were uneventfully hydrolyzed (LiOH−MeOH−H_2O), providing the benzoic acid complexes **7a**−**j** in high yield (Table 2). As anticipated, the hydrolysis of **6b** could be performed regioselectively in favor of the ester on the transition-metal-coordinated aryl group. In our preliminary study, the diaryl ether complex **7a** was treated with hot poly(phosphoric) acid in order to bring about intramolecular Friedel−Crafts acylation, and the xanthone complex **1** was isolated, albeit in modest yield (Table 3).[12a] Unfortunately, when **7b** was subjected to the same conditions it underwent demetalation. Similarly, treatment with other acids, e.g. concentrated sulfuric or methanesulfonic acid, gave no reaction at room temperature, whereas elevated temperatures decomposed the substrate. However, after methylation of the phenol, hydrolysis of the methyl ester, and conversion of the resulting **7c** into the acid chloride, a Lewis acid induced ($AlCl_3$) intramolecular Friedel−Crafts reaction was possible. A mixture of two xanthone complexes, **8a** and a minor chlorinated isomeric xanthone complex, which could not be unambiguously identified, was isolated in 48% yield (Table 3). Although discouraging, this result suggested potential access to balanol analogues, and also served to establish that Friedel−Crafts ring closures were attainable also with deactivated substrates in this class of arene−iron complexes. Recognizing the requirement for a large, nondeactivating carboxyl equivalent (R^2) in **5** (R^1 = OH), we decided to explore the dithiane group, which appeared to fulfill these criteria. The requisite diaryl ether complex **6d** was obtained in fair yield (Table 1), and exhaustive ester hydrolysis returned **7d** in excellent yield (Table 2). Unfortunately, subjecting this compound to acidic cyclization conditions ($MeSO_3H$, neat or in CH_2Cl_2) resulted in either release of the aldehyde or decomposition (Table 3). Instead, the methoxy derivative **7e** was prepared via the ester **6e** (Tables 1 and 2). Exposure of the acid chloride derived from **7e** to Lewis acidic conditions (BF_3·Et_2) did not promote the ring closure, but instead the substrate was again decomposed (Table 3). Aromatic iodides or bromides are known to be excellent partners in palladium-catalyzed carbonylation reactions.[14a] Therefore, an iodine atom appeared suitable as a large carboxyl precursor in our system. The iodo-

Table 1. Nucleophilic Aromatic Substitutions Performed on 4



Nu	R^1	R^2	product	yield[d] (%)
5a[a]	H	H	**6a**	75
5b[b]	OH	CO_2Me	**6b**	83
5c[c]	OBz	1,3-dithian-2-yl	**6d**	57
5d[b]	OMe	1,3-dithian-2-yl	**6e**	94
5e[c]	OH	I	**6f**	94
5f[b]	OMe	OMe	**6g**	93
5g[c]	OH	Me	**6h**	72[e]
5h[c]	OBz	*i*-Pr	**6j**	79

[a] NaOPh in acetone, −72 °C. [b] NaH, THF, rt. [c] K_2CO_3, DMF, rt. [d] After purification by recrystallization and/or Al_2O_3 chromatography. [e] Purity ≈ 53%; contaminated by C−C coupling products.

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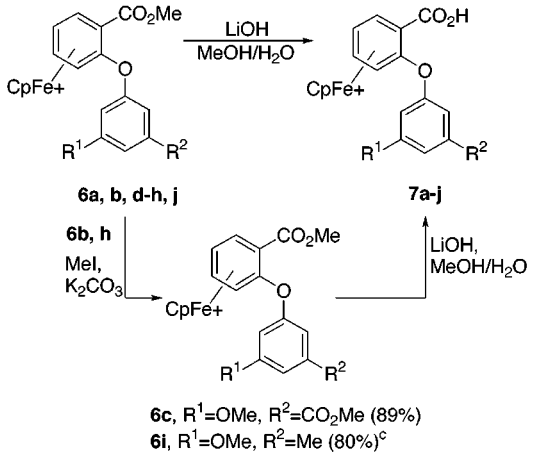
(13) Khand, I. U.; Pauson, P. L.; Watts, W. E. *J. Chem. Soc. C* **1968**, 2261. The gegenion for all cationic arene iron complexes described in this paper was hexafluorophosphate.

Table 2. Synthesis of Benzoic Acid Complexes 7a–j

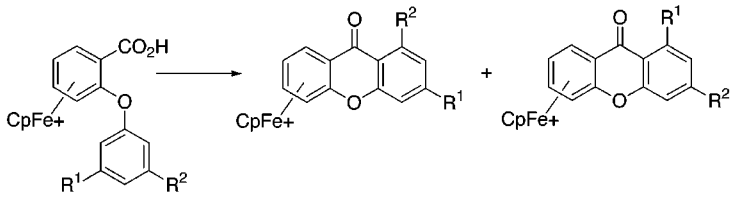


6c, R^1=OMe, R^2=CO_2Me (89%)
6i, R^1=OMe, R^2=Me (80%)[c]

compound	R^1	R^2	product	R^1	R^2	yield[a](%)
6a	H	H	**7a**	H	H	95
6b	CO_2Me	OH	**7b**	CO_2Me	OH	95
6c	CO_2Me	OMe	**7c**	CO_2Me	OMe	90
6d	1,3-dithian-2-yl	OBz	**7d**	1,3-dithian-2-yl	OH	95
6e	1,3-dithian-2-yl	OMe	**7e**	1,3-dithian-2-yl	OMe	95
6f	I	OH	**7f**	I	OH	92
6g	OMe	OMe	**7g**	OMe	OMe	96
6h	Me	OH	**7h**	Me	OH	85[b]
6i	Me	OMe	**7i**	Me	OMe	91
6j	*i*-Pr	OBz	**7j**	*i*-Pr	OH	95

[a] After purification by recrystallization. [b] Purity ≈ 60%; contaminated by C–C coupling products. [c] Based on a purity of 53% of the starting material.

Table 3. Intramolecular Friedel–Crafts Acylation Reactions



7a-j **1, 8b, d, e, g, i** **1, 8a, c, d, f, h, j**

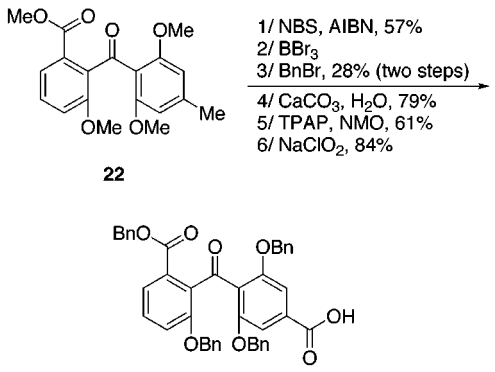
compound	R^1	R^2	conditions	products, ratio	yield(%)
7a	H	H	PPA, 80 °C	**1**	41[a]
7b	CO_2Me	OH	PPA, 50 °C	degradation	-
			H_2SO_4, rt	no reaction	
			H_2SO_4, 100 °C	degradation	
			$MeSO_3H$, 50 °C	no reaction	
			$MeSO_3H$, 100 °C	degradation	
7c	CO_2Me	OMe	1/$SOCl_2$, reflux	unknown/**8a**,	48[a]
			2/$AlCl_3$, rt	1:6[b]	
7d	1,3-dithian-2-yl	OH	$MeSO_3H$, rt	degradation	-
			$MeSO_3H$/$CH2Cl_2$, 1/9, rt	deprot. start mat.	
7e	1,3-dithian-2-yl	OMe	1/$(COCl)_2$, reflux, 2/ BF_3·OEt_2	degradation	-
7f	I	OH	$MeSO_3H$, rt	**8b**/**8c**, 2.7:1[c]	15[c]
			$MeSO_3H$, 50 °C	**8b**/**8c**, 1:4[c]	50[c]
			$MeSO_3H$ + $ZnCl_2$, rt	**8b**/**8c**, 1.6:1[c]	35[c]
7g	OMe	OMe	$MeSO_3H$, rt	**8d**	95[a]
7h	Me	OH	$MeSO_3H$, 50 °C	**8e**/**8f**, 1.2:1[c]	55
7i	Me	OMe	1/ $SOCl_2$, reflux	**8g**/**8h**, ≈1:1[c]	<10
			2/ $AlCl_3$, rt		
7j	*i*-Pr	OH	$MeSO_3H$, rt	**8i**/**8j**, 30:1[c]	72[a]

[a] After purification by recrystallization and/or Al_2O_3 chromatography. [b] Estimated from ^{1}H NMR integration. The identity of the minor product could not be established. [c] Estimated from ^{1}H NMR integration.

substituted complex **6f** was prepared (Table 1), and after saponification, the acid **7f** (Table 2) was stirred in concentrated methanesulfonic acid at room temperature. After 96 h, only 15% of xanthone complex could be isolated, together with unreacted starting material. The crude product consisted of two regioisomeric xanthones, **8b** and **8c,** in a ratio of 2.7:1 (Table 3). By increasing the

(14) (a) Schoenberg, A.; Bartoletti, I.; Heck, R. F. *J. Org. Chem.* **1974**, *39*, 3318. (b) Ritter, K. *Synthesis*, **1993**, 735.

Scheme 4

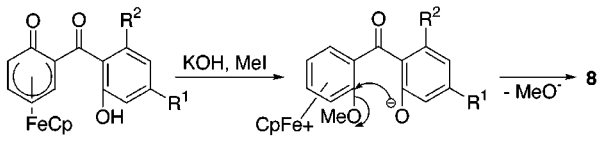


temperature to 50 °C, 50% conversion was observed after 72 h, but regioselectivity was reversed at this temperature, providing **8b** and **8c** in a ratio of 1:4 (Table 3). In an attempt to improve regioselectivity, the reaction was repeated in the presence of $ZnCl_2$. Although this additive did serve to improve selectivity (**8b**/**8c**, 1.6:1), the yield was an unsatisfactory 35% accompanied by significant decomposition (Table 3). Further attempts at resolving the problematic ring closure involved reacting **4** with commercially available 3,5-dimethoxyphenol (**5f**, Table 1), and hydrolyzing the resulting diaryl ether complex **6g** into the benzoic acid complex **7g** (Table 2), which was obtained in excellent overall yield. This symmetrical substrate, highly activated toward Friedel−Crafts acylation, appeared an ideal entry into analogues of **2** provided that the two methoxy groups could be distinguished at a later stage.[15] Indeed, upon stirring **7g** in concentrated methanesulfonic acid for 65 h, the xanthone complex **8d** was isolated in 95% yield (Table 3). Unfortunately, subsequent attempts to selectively transform the appropriate methoxy group into a carboxylic acid moiety were uniformly unsuccessful.

Naito's approach to balanol **(3)** employed methyl-substituted benzophenone **22** (Scheme 4) as an intermediate.[8c] The methyl to carboxyl transformation was realized via radical bromination, hydrolysis, and stepwise oxidation (Scheme 4). Inspired by this precedence we decided to prepare the analogous **7h**, which was not as straightforward as anticipated. As mentioned above, the presence of electron-donating R^2 groups in **5** (R^1 = OH) resulted in intractable mixtures of diaryl ether complexes and various carbon−carbon coupled products upon attempted arylation with arene−iron complex **4**. Because these byproducts could not be separated from the diaryl ether complex **6h** (Table 1), the crude mixture was hydrolyzed to **7h** (Table 2), and this mixture was dissolved in concentrated methanesulfonic acid. After stirring at rt for 5 days, a 1:1 mixture of regioisomeric xanthones **8e** and **8f** was isolated in fair yield (55% based on 53% purity of **7h**, Table 3). Treating the acid chloride derived from complex **7i** (obtained from **6h** via methylation, saponification, and reflux in thionyl chloride) with Lewis acids ($AlCl_3$ or $ZnCl_2$) gave significantly lower yields and approximately the same regioisomeric ratio (**8g** and **8h**, Table 3). Having ultimately established the suitability of an alkyl group for promoting reactivity, but not selectivity, in the cyclization, we hypothesized that an isopropyl substituent should ideally support our desired reaction sequence. The monoprotected isopropylresorcinol **5h** was synthesized from 3,5-dihydroxycarbomethoxybenzene and reacted with **4**, to give the diaryl ether complex **6j** in good yield (Table 1). After hydrolysis of both ester functionalities (Table 2), complex **7j** was dissolved in concentrated methanesulfonic acid. After stirring at rt for 48 h, the xanthone complexes **8i** and **8j** were isolated in 72% yield. Gratifyingly, excellent regiocontrol was observed (30:1, Table 3).

Nucleophilic Ring-Opening of (Xanthone)FeCp Complexes. As mentioned above, η^6-xanthone-η^5-cyclopentadienyl iron hexafluorophosphate **(1)** has been reported to undergo regioselective nucleophilic ring-opening upon reaction with amines (Scheme 1).[10] Preliminary communications have described our successful treatment of **1** with excess sodium hydroxide in aqueous methanol, delivering the isolable, zwitterionic complex **11** as a red solid (Table 4). This η^5-oxocyclohexadienyl complex was alkylated only sluggishly upon treatment with an excess of iodomethane in the presence of potassium *tert*-butoxide, but complete conversion into the dimethoxy derivative **9a** was acheived after 2 days at room temperature (Table 4). When the isopropyl-substituted xanthone complex **8i** was subjected to an excess of sodium hydroxide in aqueous methanol, a η^5-oxocyclohexadienyl complex (corresponding to **11**) was isolated in quantitative yield. Unfortunately, even after prolonged reaction times, the hydroxyl group on the coordinated arene was only partially alkylated with an excess of iodomethane in the presence of potassium *tert*-butoxide, and the yield of trimethoxy derivative **9d** was unsatisfactory (25%). The choice of potassium *tert*-butoxide as the base was made to ensure rapid and complete methylation of the hydroxyl group on the noncoordinated benzene ring, because methylation of the pseudo-carbonyl oxygen on the iron-coordinated arene was observed to promote cyclization, returning the xanthone complex **8** (Scheme 5). In early

Scheme 5



unpublished portions of this study, we noted that basic conditions promoted the former event, while acidic conditions (TMS−diazomethane/HPF_6),[16] allowed selective alkylation of the coordinated phenol. Ultimately, we managed to resolve the problematic methylation of **8i** by driving the reaction to completion with potassium hydroxide and excess iodomethane in DMSO.[17] This one-pot, tandem ring-opening/methylation reaction smoothly returned the alkylated derivatives **9b**−**d** (Table 4). Unfortunately, all attempts to distinguish between the methoxy groups in **9c** or **8d** met with failure. By treating **8d** with a large excess of boron tribromide in dichloromethane,[18] only the xanthone complex monodeprotected in the 8 position, **8k**, was isolated, albeit in

(15) If the appropriate methoxy group could be deprotected selectively, triflation would give a substrate activated towards palladium-catalyzed carbonylation (ref 14b). Furthermore, the wide range of other palladium-catalyzed reactions would be available for analogue synthesis. For a review, see: Tsuji, J. *Palladium Reagents and Catalysts: Innovations in Organic Synthesis*; Wiley: Chichester, 1995.

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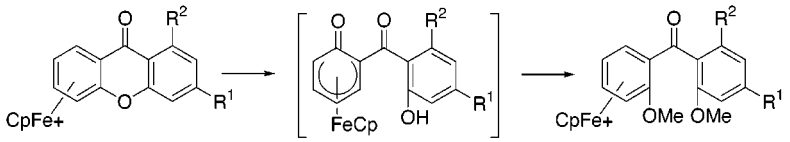
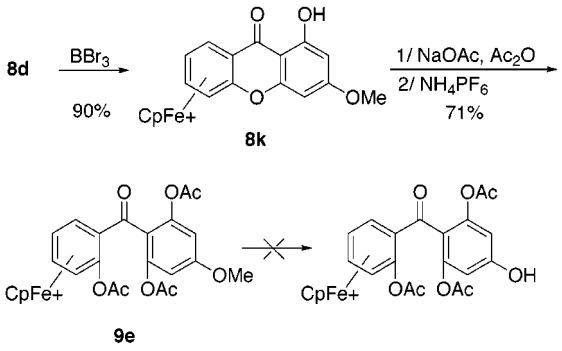
Table 4. Nucleophilic Ring-Opening of the Xanthone Complexes



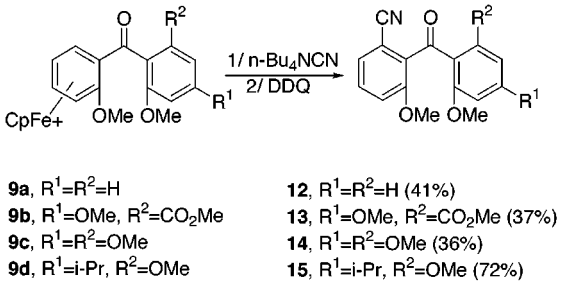
1, 8a, 8d, 8i **11: R^1=R^2=H** **9a-d**

compound	R^1	R^2	conditions	product	yield[a](%)
1	H	H	1/ NaOH, MeOH/H_2O 2/ KO*t*-Bu, MeI	**9a**	81 (over two steps)
8a	OMe	CO_2Me	KOH, MeI, DMSO	**9b**[b]	59[b]
8d	OMe	OMe	KOH, MeI, DMSO	**9c**	85
8i	*i*-Pr	OH	KOH, MeI, DMSO	**9d**	59 (R^2 = OMe)

Scheme 6



Scheme 7



9a, R^1=R^2=H
9b, R^1=OMe, R^2=CO_2Me
9c, R^1=R^2=OMe
9d, R^1=i-Pr, R^2=OMe

12, R^1=R^2=H (41%)
13, R^1=OMe, R^2=CO_2Me (37%)
14, R^1=R^2=OMe (36%)
15, R^1=i-Pr, R^2=OMe (72%)

excellent yield (90%) (Scheme 6). Various other reagents (TMSI,[19] NaS*i*-Pr in DMF,[20] and NaHMDS in DMEU[21]) likewise failed to provide the desired dihydroxy xanthone or the compound monoprotected in the 8 position. In some cases, acetoxy groups have been shown to be orthogonal to methoxy groups upon treatment with boron tribromide at low temperatures.[22] Interestingly, nucleophilic ring-opening and triacetylation to the benzophenone **9e** were smoothly achieved in good yield by treating **8k** with sodium acetate in acetic anhydride (Scheme 7). However, in our hands, selective cleavage of the methyl ether of **9e** could not be realized, even at −78 °C.

Cyanide Addition/Oxidative Decomplexation. Certain electron-withdrawing substituents have been found to facilitate regioselective addition of cyanide ion to arene−iron complexes, furnishing isolable, neutral pentahapto complexes which could be oxidatively demetalated in a subsequent step (Scheme 2).[11] In our case, the arene−iron substrates **9a**−**d** displayed reversible addition of cyanide ion, a feature which prevented isolation of the adducts. However, the cyanide addition/decomplexation sequence could be accomplished in a one-pot procedure, employing a mixture of tetrabutylammonium cyanide and DDQ in dichloromethane. In this manner, the xanthone complexes **9a**−**d** were functionalized and demetalated, providing the heavily substituted benzophenones **12**−**15** (Scheme 7). Separate experiments showed **9a**−**d** stable to DDQ at rt for 24 h. Unfortunately, all attempts to regioselectively, or alternatively fully, deprotect **14** were unsuccessful.

Completion of the Synthesis of 18. As expected, conditions allowing single-step conversion of the isopropyl group into a carboxylic acid (HNO_3)[23] turned out to be too harsh when applied to **15**, necessitating the development of a stepwise procedure. Benzophenone **15** was reacted with *N*-bromosuccinimide in the presence of AIBN,[24] furnishing two benzophenones. The crude mixture, consisting of the α-brominated isopropylbenzophenone and the corresponding isopropenyl-substituted compound, was homogenized to the latter via base-induced elimination of HBr, employing sodium acetate in DMF.[25] Due to the tendency of this material to polymerize when contacted with silica gel, no purification was performed. The crude mixture was immediately oxidized, via a Lemieux−Johnson procedure,[26] providing methyl ketone **16** in good yield (70% over three steps) after silica-gel flash chromatography (Scheme 8). A classical haloform reaction[27] transformed the ketone into the desired benzoic acid **17** derivative in fair yield (56%). Attempts to hydrolyze the nitrile functionality using standard conditions (sulfuric acid at various temperatures[28] or highly alkaline conditions[29]) did not give the expected product; only complex mixtures and degradation products were isolated. However, after warming the nitrile in a mixture of concentrated hydrochloric acid and methanol, and subsequent careful base treatment, the diacid **18** could be isolated in acceptable yield (Scheme 8). Compound **18** was an intermediate in Vicker's total synthesis of balanol.[8h]

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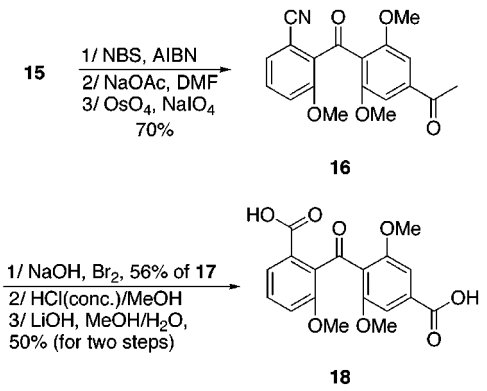
Scheme 8



Conclusions

We have developed arene−iron mediated paths to unsymmetrically substituted benzophenones, an important class of compounds not readily accessible by conventional routes. By performing a formal synthesis of the benzophenone appendage of the PKC-inhibitor Balanol, we have shown that combining iron-assisted reactions can be useful in the preparation of complex molecules. We have performed the first Friedel−Crafts reactions with iron-bound benzoic acids. We have also extended Sutherland's pioneering studies on regioselective ring-opening of the parent xanthone complex with amines and stabilized carbon nucleophiles to include regioselective ring-opening of substituted xanthone complexes, using hydroxide or acetate as nucleophiles. Although the generality of the overall methodology is limited by the restrictions put on substituents in the Friedel−Crafts reaction, a wide range of unsymmetrically substituted benzophenones should be available via the paths described in this paper.

Experimental Section

General. All reactions involving iron complexes were performed in the dark, in aluminum-foil-wrapped flasks. Solvents and reagents were used as received from commercial sources, unless otherwise indicated. NMR spectra were recorded at 400.132 MHz (^{1}H) or 100.6 MHz (^{13}C). The chemical shifts are given relative to residual protio resonances of the deuterated solvent used. FABMS spectra were recorded using *p*-nitrobenzyl alcohol as a matrix in positive mode and EI spectra were recorded at 70 eV. TLC analyses employed Merck aluminum-backed sheets precoated with silica gel 60 F254. Visualization was accomplished using UV-light. Flash chromatography separations were performed by using Matrex silica gel. Alumina purifications were performed using Merck aluminum oxide 90, neutral. Recrystallizations of iron complexes were performed by dissolving the complex in the minimum volume of acetone and adding approximately 10 vol of diethyl ether. The precipitated crystals were collected by suction filtration. Melting points were uncorrected. Elemental analyses were obtained from H. Kolbe Mikroanalytisches Laboratorium, Mülheim a. d. Ruhr, Germany.

CAUTION! Alkylammonium cyanide compounds are highly toxic and are readily absorbed through the skin.

***η*^{6}-2-Chlorocarboxybenzene-*η*^{5}-cyclopentadienyl Iron Hexafluorophosphate (10).** To a 500-mL round-bottomed flask, equipped with a reflux condensor were added *η*^{6}-2-chlorotoluene-*η*^{5}-cyclopentadienyl iron hexafluorophosphate[13] (20.02 g, 51 mmol), $KMnO_4$ (29.84 g, 189 mmol), $MgSO_4$ (13.49 g, 112 mmol), and 250 mL of water. The reaction mixture was refluxed for 9 h after which the hot mixture was filtered through a Büchner funnel. To destroy the excess $KMnO_4$, $Na_2S_2O_5$ was added, and the resulting yellow solution was cooled on an ice bath. Addition of HPF_6 (60% in water) (20 mL, 136 mmol) afforded a yellow precipitate. The yellow crystals were filtered off and the yellow filtrate was extracted with nitromethane until colorless. After drying (Na_2SO_4), evaporation of the solvent returned additional solid, which was combined with the precipitate above and dissolved in the minimum volume of acetone. The addition of a large excess of dichloromethane (approximately 5 vol) resulted in a white precipitate, consisting of unwanted salts. After filtration and evaporation the procedure was repeated until the residue was completely soluble in dichloromethane. Evaporation afforded crude material which was recrystallized from acetone−diethyl ether. Filtration gave the title compound as a yellow powder (17.98 g, 83%). Mp ≈ 200 °C dec. IR (KBr): 3100, 1730, 1510, 850 cm^{-1}. HRMS−FAB$^+$ (*m*/*z*): M$^+$ calcd for $C_{12}H_{10}ClFeO_2$, 276.9719; found, 276.9724. ^{1}H NMR (CD_3COCD_3): *δ* 5.40 (s, 5H), 6.65 (t, *J* = 6.1 Hz, 1H), 6.76 (t, *J* = 6.2 Hz, 1H), 6.98 (d, *J* = 6.2 Hz, 1H), 7.01 (d, *J* = 6.1 Hz, 1H). ^{13}C NMR (CD_3COCD_3): *δ* 81.6 (Cp), 88.3, 89.5, 90.4, 90.6, 94.0, 106.0, 165.4.

***η*^{6}-2-Chlorocarbomethoxybenzene-*η*^{5}-cyclopentadienyl Iron Hexafluorophosphate (4).** To a 1-L round-bottomed flask, equipped with a reflux condenser and a gas trap, the complex **10** (14.57 g, 34.5 mmol) and 400 mL of $SOCl_2$ were added. The mixture was refluxed for 3 h, and the excess thionyl chloride was removed by evaporation. By coevaporating the mixture with CH_2Cl_2, the last remnants of thionyl chloride were removed. The resulting yellow crystalline oil was immediately dissolved in 400 mL of methanol, and stirred at rt under Ar for 2 h. During this time, the product started to precipitate. The methanol was removed under reduced pressure, and the residue was recrystallized from acetone−diethyl ether. Filtration gave the title product as yellow crystals, 13.70 g (91%). Mp ≈ 125 °C dec. IR (KBr): 3110, 2960, 1740, 1270, 850 cm^{-1}. HRMS−FAB$^+$ (*m*/*z*): M$^+$ calcd for $C_{13}H_{12}ClFeO_2$, 290.9875; found, 290.9875. ^{1}H NMR (CD_3COCD_3): *δ* 4.09 (s, 3H), 5.43 (s, 5H), 6.70 (t, *J* = 6.1 Hz, 1H), 6.81 (t, *J* = 6.1 Hz, 1H), 7.02 (d, *J* = 6.2 Hz, 2H). ^{13}C NMR (CD_3COCD_3): *δ* 54.8, 81.8 (Cp), 88.5, 89.6, 90.62, 90.65, 94.9, 106.5, 165.1.

***η*^{6}-2-Phenoxycarbomethoxybenzene-*η*^{5}-cyclopentadienyl Iron Hexafluorophosphate (6a).** Sodium phenoxide[30] (0.273 g, 2.34 mmol) was dissolved in 40 mL of dry acetone at rt. After the solution was cooled to −70 °C, **4** (1.00 g, 2.29 mmol) was added in one portion. The resulting yellow solution was stirred at −70 °C for 5 h, after which it was concentrated to approximately 10 mL, and the product was precipitated by the addition of approximately 50 mL of diethyl ether. Filtration afforded a brownish-yellow solid material which was recrystallized from acetone−diethyl ether. Filtration gave the title compound as a yellow powder, 0.812 g (71%). Mp ≈ 135 °C dec. IR (KBr): 3105, 3095, 1735, 1630, 1590, 1280, 1250, 825 cm^{-1}. HRMS−FAB$^+$ (*m*/*z*): M$^+$ calcd for $C_{19}H_{17}FeO_3$, 349.0527; found, 349.0536. ^{1}H NMR (CD_3COCD_3): *δ* 4.03 (s, 3H), 5.35 (s, 5H), 6.32 (d, *J* = 6.7 Hz, 1H), 6.48 (t, *J* = 6.0 Hz, 1H), 6.57 (t, *J* = 6.0 Hz, 1H), 6.91 (d, *J* = 6.1 Hz, 1H), 7.35 (d, *J* = 7.8 Hz, 2H), 7.40 (t, *J* = 7.6 Hz, 1H), 7.57 (t, *J* = 8.0 Hz, 2H). ^{13}C NMR (CD_3COCD_3): *δ* 54.4, 78.0, 80.0 (Cp), 85.2, 86.0, 88.7, 89.0, 121.4, 127.5, 131.8, 132.9, 154.8, 165.5.

General Procedures for Nucleophilic Aromatic Substitutions Performed On 4 (Table 1). Procedure A. Sodium hydride (60% dispersion in mineral oil) (1.1 mmol) was placed in a two-necked flask under Ar and washed with 3 × 10 mL of dry pentane. Dry THF (10 mL) was added, followed by the phenol (1.1 mmol). After the mixture was stirred at rt for 30 min, 10 mL of THF and **4** (1 mmol) were added sequentially, and the mixture was stirred at rt until no more starting material was present (TLC, SiO_2, MeOH/NH_4Cl (2 M)/$MeNO_2$, 7/2/1). The solution was then diluted with 40 mL of dichloromethane, transferred into a separatory funnel, and washed with 3 × 20 mL of water containing approximately 1 g of NH_4PF_6 per portion. Drying over Na_2SO_4, filtration, and evaporation afforded crude material which was purified by

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recrystallization from acetone−diethyl ether. The resulting yellow crystals were filtered, dried under vacuum, and analyzed. In the case of diphenols as nucleophiles, the method was slightly altered. To avoid triaryldiether formation, the stoichiometry was adjusted to 4:2:1 (diphenol/NaH/iron-complex),[31] and the reaction mixture was made acidic by the addition of 10% HCl (aq) when quenched.

Procedure B. The nucleophile (1.1 mmol), K_2CO_3 (5 mmol), and **4** (1 mmol) were dissolved in 20 mL of dry DMF. The mixture was stirred at rt until no more starting material was present (TLC, SiO_2, MeOH/NH_4Cl (2 M)/$MeNO_2$, 7/2/1). a few drops of the reaction mixture were withdrawn and dissolved in 0.5 mL of dichloromethane and extracted with 0.5 mL of water containing one spatula of NH_4PF_6). The solution was then diluted with 50 mL of dichloromethane and transferred into a separatory funnel, where it was washed with 5 × 50 mL of water containing approximately 1 g of NH_4PF_6 per portion. Drying over Na_2SO_4, filtration, and evaporation afforded crude material which was recrystallized from acetone−diethyl ether. The resulting yellow crystals were filtered, dried under vacuum, and analyzed.

***η*⁶-2-(3-Methoxy-5-carbomethoxyphenoxy)-carbomethoxybenzene-*η*⁵-cyclopentadienyl Iron Hexafluorophosphate (6c).** The phenol **6b** (0.989 g, 1.735 mmol) was dissolved in 15 mL of dry DMF. Then MeI (1.2 mL, 19.3 mmol) and K_2CO_3 (2.502 g, 18.1 mmol) were added. The yellow solution, containing solid K_2CO_3, was stirred at rt under Ar for 18 h. The excess K_2CO_3 was filtered off, 50 mL of CH_2Cl_2 was added, and the yellow solution was washed with 5 × 40 mL of water containing approximately 1 g of NH_4PF_6 per portion. Drying over Na_2SO_4, filtration, and evaporation afforded crude material which was purified by recrystallization from acetone−diethyl ether. Filtration gave the title compound as a yellow powder, 0.770 g (76%). Mp ≈ 185 °C dec. Anal. Calcd for $C_{22}H_{21}F_6FeO_6P$: C, 45.39; H, 3.64. Found: C, 45.48; H, 3.73. IR (KBr): 3096, 2950, 1739, 1707, 1594, 1305, 1255, 829 cm^{-1}. HRMS−FAB$^+$ (*m*/*z*): M^+ calcd for $C_{22}H_{21}FeO_6$, 437.0687; found, 437.0688. ^1H NMR (CD_3COCD_3): *δ* 3.89 (s, 3H), 3.92 (s, 3H), 4.03 (s, 3H), 5.39 (s, 5H), 6.53 (m, 2H), 6.62 (t, *J* = 5.8 Hz, 1H), 6.95 (dd, *J* = 6.2, 1.3 Hz, 1H), 7.17 (t, *J* = 2.3 Hz, 1H), 7.40 (dd, *J* = 2.1, 1.2 Hz, 1H), 7.48 (dd, *J* = 2.3, 1.2 Hz, 1H). ^{13}C NMR (CD_3COCD_3): *δ* 52.4, 53.9, 56.0, 79.1, 79.7 (Cp), 85.0, 85.9, 88.3, 88.7, 110.9, 112.7, 112.8, 131.2, 133.8, 155.9, 162.0, 164.8, 165.6.

General Procedure for Ester Hydrolysis (Table 2). The ester (1.0 mmol) was placed in a 100-mL flask and 30 mL of methanol was added (the ester complexes were generally of very low solubility in methanol). LiOH (1.2 mmol) dissolved in 10 mL of water was added and the resulting solution was stirred at rt until no more starting material was present (TLC, SiO_2, MeOH/NH_4Cl (2 M)/$MeNO_2$, 7/2/1). The reaction was quenched by acidification with 10% HCl (aq); the mixture was diluted with 100 mL of dichloromethane and transferred into a separatory funnel, where it was washed with 3 × 20 mL of water containing approximately 1 g of NH_4PF_6 per portion. Drying over Na_2SO_4, filtration, and evaporation afforded crude material which was purified by recrystallization from acetone−diethyl ether. The resulting yellow crystals were filtered, dried under vacuum, and analyzed.

***η*⁶-Xanthone- *η*⁵-cyclopentadienyl Iron Hexafluorophosphate (1).[10]** The benzoic acid complex **7a** (0.098 g, 0.204 mmol) was dissolved in 20 g of polyphosphoric acid and heated, while being mechanically stirred, at 80 °C for 3 h. The black reaction mixture was then cooled to rt, diluted with 20 mL of water, and transferred into a separatory funnel, where it was extracted with 2 × 30 mL of CH_2Cl_2 and 2 × 30 mL of CH_3NO_2. After the addition of approximately 1 g of NH_4PF_6, the aqueous phase was extracted with CH_2Cl_2 until colorless. The organic phases were combined, and after drying over Na_2SO_4, filtration, and evaporation of the solvent, a yellow-brownish semisolid remained. This material was recrystallized from acetone−diethyl ether, to give 0.037 g of yellow-brown crystals, consisting of the title compound (42%). ^1H NMR (CD_3COCD_3): *δ* 5.24 (s, 5H), 6.73 (t, *J* = 6.2 Hz, 1H), 6.92 (dt, *J* = 6.4, 1.2 Hz, 1H), 7.25 (dd, *J* = 6.2, 1.2 Hz, 2H), 7.62−7.69 (m, 2H), 8.02 (dt, *J* = 7.2, 1.8 Hz, 1H), 8.31 (dd, *J* = 8.0, 1.6 Hz, 1H).

***η*⁶-8-Carbomethoxy-6-methoxyxanthone-*η*⁵-cyclopentadienyl Iron Hexafluorophosphate (8a).** In a 100-mL round-bottomed flask, equipped with a gas trap, the complex **7d** (1.00 g, 1.76 mmol) was dissolved in 40 mL of thionyl chloride and refluxed for 5 h. The excess reagent was removed under reduced pressure. By coevaporating the mixture with CH_2Cl_2, the last remnants of thionyl chloride were removed. The resulting yellow crystalline oil was immediately dissolved in 100 mL CH_2Cl_2, and $AlCl_3$ (4.72 g, 35.4 mmol) was added. After the mixture was stirred at rt under Ar for 24 h, the reaction was quenched by the careful addition of 30 mL of ice−water. After the addition of 3 g of NH_4PF_6, the yellow aqueous phase was extracted with 4 × 30 mL of CH_2Cl_2. The organic phases were combined and washed with 50 mL of water. After this was dried over $MgSO_4$, filtered, and evaporated, a dark yellow residue was left. This material was purified by chromatography on neutral Al_2O_3 (the column was rinsed with diethyl ether, after which the product was eluted with acetone), providing yellow-brown crystals (0.461 g, 48%) consisting of the title compound and a chlorinated byproduct in the ratio of 6:1. IR (NaCl plates, CH_2Cl_2): 3105, 2953, 1734, 1674, 1575, 1303, 1226, 1130, 850 cm^{-1}. HRMS−FAB$^+$ (*m*/*z*): M^+ calcd for $C_{21}H_{17}FeO_5$, 405.0425; found, 405.0432.^1H NMR (CD_3COCD_3): *δ* 3.97 (s, 3H), 4.09 (s, 3H), 5.22 (s, 5H), 6.70 (t, *J* = 6.2 Hz, 1H), 6.88 (t, *J* = 6.7 Hz, 1H), 7.16 (d, *J* = 2.3 Hz, 1H), 7.20 (d, *J* = 6.5 Hz, 2H), 7.25 (d, *J* = 2.3 Hz, 1H). ^{13}C NMR (CD_3COCD_3): *δ* 53.4, 57.5, 79.0, 79.7 (Cp), 80.5, 83.0, 88.4, 90.5, 103.7, 111.2, 114.5, 130.7, 137.1, 159.6, 167.0, 168.6, 177.5.

***η*⁶-6,8-Dimethoxyxanthone-*η*⁵-cyclopentadienyl Iron Hexafluorophosphate (8d).** The complex **7g** (0.167 g, 0.308 mmol) was dissolved in 5 mL of methanesulfonic acid and stirred at rt for 65 h. The red-brown reaction mixture was then cooled to 0 °C, diluted with 15 mL of water, and transferred into a separatory funnel. After the addition of approximately 2 g of NH_4PF_6, the aqueous phase was extracted with 2 × 50 mL CH_2Cl_2. After this was dried over Na_2SO_4, filtered, and evaporated, a brown-yellow residue was left. This material was recrystallized from acetone−diethyl ether, providing the title compound as yellow-brown crystals (0.152 g, 95%). Mp ≈ 200 °C dec. Anal. Calcd for $C_{20}H_{17}F_6FeO_4P$: C, 46.00; H, 3.28. Found: C, 45.88; H, 3.34. IR (KBr): 3096, 3041, 2995, 1671, 1616, 1570, 1282, 1214, 1163, 829 cm^{-1}. ^1H NMR (CD_3COCD_3): *δ* 4.02 (br s, 6H), 5.18 (s, 5H), 6.61 (t, *J* = 6.1 Hz, 1H), 6.65−6.69 (m, 1H), 6.77 (t, *J* = 5.9 Hz, 1H), 7.06 (d, *J* = 6.6 Hz, 1H), 7.17 (d, *J* = 6.6 Hz, 1H). ^{13}C NMR (CD_3COCD_3): *δ* 56.9, 57.1, 78.2, 79.3 (Cp), 81.6, 83.2, 87.7, 89.8, 95.4, 97.1, 105.7, 130.2, 160.6, 163.6, 167.8, 175.3.

***η*⁶-8-Hydroxy-6-isopropylxanthone-*η*⁵-cyclopentadienyl Iron Hexafluorophosphate (8i).** The benzoic acid complex **7j** (0.157 g, 0.292 mmol) was dissolved in 5 mL of methanesulfonic acid and stirred at rt for 4 days. The dark brown reaction mixture was then cooled to 0 °C, diluted with 20 mL of water, and transferred into a separatory funnel. After the addition of 2 g of NH_4PF_6, the aqueous phase was extracted with 4 × 30 mL of CH_2Cl_2. After this was dried over Na_2SO_4, filtered, and evaporated, a dark greenish residue was left. This material was dissolved in the minimum volume of CH_2Cl_2 and approximately 10 vol of diethyl ether was added. This led to the precipitation of yellow-brown crystals (0.109 g, 72%), consisting of the title compound and its regioisomer in the ratio of 30:1. Anal. Calcd for $C_{21}H_{19}F_6FeO_3P$: C, 48.49; H, 3.68. Found: C, 48.35; H, 3.74. IR (NaCl plates, CH_2Cl_2): 3500−2500, 3068, 2977, 1717, 1287, 1227, 761 cm^{-1}. HRMS−FAB$^+$ (*m*/*z*): M^+ calcd for $C_{21}H_{19}FeO_3$, 375.0684; found, 375.0692. ^1H NMR (CD_3COCD_3): *δ* 1.32 (d, *J* = 6.9 Hz, 6H), 3.08 (sep, *J* = 6.9 Hz, 1H), 5.30 (s, 5H), 6.73 (t, *J* = 5.8 Hz, 1H), 6.90 (d, *J* = 1.1 Hz, 1H), 6.92 (t, *J* = 5.9 Hz, 1H), 7.01 (d, *J* = 1.1 Hz, 1H), 7.20 (d, *J* = 6.4 Hz, 1H), 7.29 (d, *J* = 6.0 Hz, 1H), 11.60 (s, 1H). ^{13}C NMR (CD_3COCD_3): *δ* 23.44, 23.49, 35.9, 78.6, 79.4,

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79.9 (Cp), 82.7, 88.2, 90.7, 106.7, 107.2, 111.7, 131.0, 157.1, 162.8, 163.4, 185.0.

***η*⁶-8-Hydroxy-6-methoxyxanthone-*η*⁵-cyclopentadienyl Iron Hexafluorophosphate (8k).** The xanthone complex **8d** (0.094 g, 0.180 mmol) was dissolved, with difficulty, in 15 mL of CH_2Cl_2. To the yellow solution was added BBr_3 (0.100 mL, 1.046 mmol) via syringe, and the resulting orange solution was stirred at rt for 3.5 h. To the orange reaction mixture was added 10 mL of water, and the solution was transferred into a separatory funnel. After the addition of approximately 2 g of NH_4PF_6, the phases were separated. The aqueous phase was extracted with 5 × 10 mL of CH_2Cl_2. After this was dried over Na_2SO_4, filtered, and evaporated, yellow crystals remained. This material was recrystallized from acetone−diethyl ether, providing the title compound as yellow crystals (0.082 g, 90%). IR (NaCl plates, CH_2Cl_2): 3105, 2959, 1657, 1602, 1332, 1182, 1159, 857 cm^{-1}. HRMS−FAB$^+$ (*m*/*z*): M^+ calcd for $C_{19}H_{15}FeO_4$, 363.0320; found, 363.0326. ^1H NMR (CD_3COCD_3): *δ* 4.03 (s, 3H), 5.30 (s, 5H), 6.54 (d, *J* = 2.2 Hz, 1H), 6.66 (d, *J* = 2.2 Hz, 1H), 6.72 (t, *J* = 6.1 Hz, 1H), 6.90 (t, *J* = 6.1 Hz, 1H), 7.19 (d, *J* = 6.5 Hz, 1H), 7.26 (d, *J* = 5.9 Hz, 1H), 11.94 (s, 1H). ^{13}C NMR (CD_3COCD_3): *δ* 57.2, 78.0, 79.6, 80.0 (Cp), 82.7, 88.2, 90.6, 96.1, 99.1, 103.1, 130.7, 158.6, 164.6, 169.5, 183.4.

(2,3,4,5,6)-*η*⁵-[2-(2-Hydroxybenzoyl)-oxocyclohexadienyl]-*η*⁵-cyclopentadienyl Iron (11). The xanthone complex **1** (1.00 g, 2.17 mmol) was partially dissolved in 75 mL of methanol. Sodium hydroxide (0.864 g, 21.6 mmol) dissolved in 30 mL of water was added, which led to complete dissolution and a color change from yellow to red. The reaction mixture was stirred at rt for 4 h, after which it was acidified (pH ≈ 6) by the dropwise addition of 10% HCl (aq). Extraction with 5 × 30 mL of CH_2Cl_2, drying over Na_2SO_4, filtration, and evaporation of the solvent provided a red-brown solid residue. After purification by filtration through a short plug of silica ($MeOH-CH_2Cl_2$), a red-brown fluffy solid (0.723 g, 100%) was isolated. Mp ≈ 100 °C dec. IR (KBr): 3500−2500, 3100, 3040, 1620, 1600, 1530 cm^{-1}. HRMS−FAB$^+$ (*m*/*z*): $[M+H]^+$ calcd for $C_{18}H_{15}FeO_3$, 335.0371; found, 335.0335. ^1H NMR ($CD_3COCD_3-CDCl_3$): *δ* 4.78 (s, 5H), 5.12 (d, *J* = 6.0 Hz, 1H), 5.63 (t, *J* = 5.5 Hz, 1H), 5.73−5.80 (m, 2H), 6.74 (t, *J* = 7.5 Hz, 1H), 6.88 (d, *J* = 8.3 Hz, 1H), 7.37−7.46 (m, 2H), 12.13 (br s, 1H). ^{13}C NMR ($CD_3COCD_3-CDCl_3$): *δ* 72.8, 74.0, 75.4 (Cp), 86.4, 87.5, 90.6, 118.0, 119.2, 120.6, 134.1, 136.8, 151.2, 162.5, 202.9.

***η*⁶-2-(2-Methoxybenzoyl)-methoxybenzene-*η*⁵-cyclopentadienyl Iron Hexafluorophosphate (9a).** The neutral red oxocyclohexadienyl complex **11** (0.604 g, 1.808 mmol) was dissolved in 75 mL of acetone−dichloromethane, 2:1. To this, KO*t*-Bu (1.028 g, 9.17 mmol) and MeI (3.0 mL, 48.2 mmol) were added, and the solution was stirred at rt under Ar for 48 h. The resulting yellow solution, containing solid white material, was evaporated, and the residual orange oil was dissolved in 15 mL of acetone. A solution of 5 g of NH_4PF_6 in 15 mL of water was added. Evaporation of the acetone precipitated yellow crystals from the remaining aqueous solution. After filtration, drying, and recrystallization from acetone−diethyl ether, 0.747 g of yellow crystals consisting of the title product was isolated (81%). Mp ≈ 200 °C dec. IR (KBr): 3100, 2960, 1655, 1570, 1300, 825 cm^{-1}. HRMS−FAB$^+$ (*m*/*z*): M^+ calcd for $C_{20}H_{19}FeO_3$, 363.0683; found, 363.0682. ^1H NMR (CD_3COCD_3): *δ* 3.52 (s, 3H), 3.99 (s, 3H), 5.26 (s, 5H), 6.35 (dt, *J* = 6.5, 1.5 Hz, 1H), 6.48−6.56 (m, 3H), 7.09−7.17 (m, 2H), 7.67 (dt, *J* = 7.0, 1.7 Hz, 1H), 7.92 (dd, *J* = 7.7, 1.7 Hz, 1H). ^{13}C NMR (CD_3COCD_3): *δ* 56.0, 58.0, 71.2, 78.7 (Cp), 83.5, 87.5, 87.7, 99.4, 113.5, 121.9, 126.8, 131.3, 132.4, 137.1, 160.7, 191.1.

***η*⁶-2-(2-Carbomethoxy-4,6-dimethoxybenzoyl)-methoxybenzene-*η*⁵-cyclopentadienyl Iron Hexafluorophosphate (9b).** To 15 mL of dry DMSO, powdered KOH (0.115 g, 2.06 mmol) was added followed by **8a** (0.099 g, 0.180 mmol) and MeI (0.5 mL, 8.0 mmol). The yellow solution, which quickly darkened, was stirred at rt in a sealed vessel for 2 h, after which a new portion of KOH-MeI was added. After stirring for 14 h, 30 mL of water containing 1 g of NH_4PF_6 was added to the brown-yellow solution. The mixture was acidified with 10% HCl (aq) and transferred into a separatory funnel. Extraction with 2 × 25 mL of CH_2Cl_2 and 1 × 20 mL of $CH_2Cl_2-CH_3NO_2$, 1:1, gave a yellow organic phase which was washed with 3 × 40 mL of water. After this was dried over $MgSO_4$, filtered, and evaporated a yellow-brownish semisolid was left. This was purified by recrystallization from acetone−diethyl ether, followed by chromatography on neutral Al_2O_3, (the column was rinsed with diethyl ether, after which the product was eluted with acetone), providing yellow crystals (0.063 g, 59%) consisting of the title compound and an unknown iron complex in a ratio of 6:1. IR (NaCl plates, CH_2Cl_2): 3057, 2951, 1713, 1678, 1580, 1265, 1217, 845 cm^{-1}. HRMS−FAB$^+$ (*m*/*z*): M^+ calcd for $C_{23}H_{23}FeO_6$, 451.0844; found, 451.0851. ^1H NMR (CD_3COCD_3): *δ* 3.81 (s, 3H), 3.83 (s, 3H), 3.92 (s, 3H), 3.94 (s, 3H), 5.25 (s, 5H), 6.44 (t, *J* = 6.2 Hz, 1H), 6.55 (d, *J* = 6.6 Hz, 1H), 6.59 (d, *J* = 6.3 Hz, 1H), 6.76 (dd, *J* = 6.2, 1.3 Hz, 1H), 6.92 (d, *J* = 2.2 Hz, 1H), 7.07 (d, *J* = 2.2 Hz, 1H). ^{13}C NMR (CD_3COCD_3): *δ* 53.2, 56.4, 56.9, 58.1, 72.2, 78.3, 79.1 (Cp), 79.7, 85.3, 88.4, 89.2, 103.1, 107.4, 132.4, 134.2, 159.6, 163.4, 167.5, 193.4.

***η*⁶-2-(2,4,6-trimethoxybenzoyl)-methoxybenzene-*η*⁵-cyclopentadienyl Iron Hexafluorophosphate (9c).** To 30 mL of dry DMSO, powdered KOH (0.341 g, 6.08 mmol) was added followed by **8d** (0.300 g, 0.574 mmol) and MeI (0.75 mL, 12.0 mmol). The yellow solution, which quickly turned brown-red, was stirred for 1 h at rt under Ar, after which a new portion of KOH−MeI was added. This was repeated twice, after which the mixture was allowed to stir at rt for 3 h. To the brown-red solution was then added 50 mL of water containing approximately 2 g of NH_4PF_6, and the mixture was acidified with 10% HCl (aq), which turned it yellow. Extraction with 3 × 50 mL of CH_2Cl_2 and 1 × 25 mL of CH_3NO_2 gave a yellow organic phase which was washed with 4 × 50 mL of water. To the organic phase was added 20 mL of water containing 5 g of NH_4PF_6. The organic solvent was evaporated off, and the remaining aqueous solution was extracted with 3 × 40 mL of CH_2Cl_2. After this was dried over Na_2SO_4, filtered, and evaporated, a yellow-brown oil was left. This was dissolved in the minimum volume of acetone, and the addition of approximately 5 volof diethyl ether led to the precipitation of the title compound as yellow crystals, 0.279 g (85%). IR (NaCl plates, CH_2Cl_2): 3114, 2950, 1666, 1598, 1470, 1282, 1223, 1170, 857 cm^{-1}. HRMS−FAB$^+$ (*m*/*z*): M^+ calcd for $C_{22}H_{23}FeO_5$, 423.0895; found, 423.0887. ^1H NMR (CD_3COCD_3): *δ* 3.73 (s, 6H), 3.90 (s, 3H), 3.98 (s, 3H), 5.18 (s, 5H), 6.32 (s, 1H), 6.34 (t, *J* = 6.0 Hz, 1H), 6.51−6.57 (m, 3H). ^{13}C NMR (CD_3COCD_3): *δ* 56.2, 56.5, 58.1, 72.1, 78.8 (Cp), 84.6, 88.0, 88.6, 92.0, 93.5, 112.3, 134.1, 161.1, 165.5, 190.3.

***η*⁶-2-(4-Isopropyl-2,6-dimethoxybenzoyl)-methoxybenzene-*η*⁵-cyclopentadienyl Iron Hexafluorophosphate (9d).** To 30 mL of dry DMSO, the xanthone complex **8i** (0.339 g, 0.651 mmol) was added followed by powdered KOH (0.30 g, 5.29 mmol) and MeI (0.82 mL, 13.2 mmol). The yellow solution, which quickly darkened, was stirred for 1 h at rt under Ar, after which a new portion of KOH−MeI was added. This was repeated three times, giving a total reaction time of 5 h. To the brownish-yellow solution was then added 50 mL of water containing approximately 2 g of NH_4PF_6, and the mixture was acidified with 10% HCl (aq). Extraction with 3 × 50 mL of CH_2Cl_2 and 2 × 25 mL of CH_3NO_2 gave a yellow organic phase which was washed with 4 × 100 mL of water. After this was dried over Na_2SO_4, filtered, and evaporated a yellow-brownish semisolid was left. This was dissolved in the minimum vol of acetone, and the addition of approximately 5 vol of diethyl ether led to the precipitation of the title compound as yellow crystals, 0.222 g (59%). HRMS−FAB$^+$ (*m*/*z*): M^+ calcd for $C_{24}H_{27}FeO_4$, 435.1259; found, 435.1248. ^1H NMR (CD_3COCD_3): *δ* 1.28 (d, *J* = 6.9 Hz, 6H), 2.97 (sep, *J* = 6.9 Hz, 1H), 3.78 (s, 3H), 3.95 (s, 3H), 5.19 (s, 5H), 6.37 (dt, *J* = 6.0, 1.3 Hz, 1H), 6.53−6.59 (m, 2H), 6.63 (dd, *J* = 6.3, 1.2 Hz, 1H), 6.69 (s, 2H). ^{13}C NMR (CD_3COCD_3): *δ* 24.0, 35.9, 56.5, 58.1, 66.8, 72.5, 78.9 (Cp), 85.0, 88.3, 88.7, 90.7, 103.5, 134.7, 155.9, 159.1, 192.3.

***η*⁶-2-(2,6-Diacetoxy-4-methoxybenzoyl)-acetoxybenzene-*η*⁵-cyclopentadienyl Iron Hexafluorophosphate (9e).** To 10 mL of acetic anhydride, sodium acetate (0.262 g, 3.20 mmol) was added followed by **8k** (0.080 g, 0.158 mmol). The yellow

solution was stirred at rt for 21 h. After the solution was diluted with 60 mL of CH_2Cl_2 and washed with 3 × 30 mL of 1M $NaHCO_3$ (aq), the organic phase was added to 10 mL of water containing 3 g of NH_4PF_6. The organic solvent was evaporated, and the yellow aqueous phase was extracted with 30 mL of CH_2Cl_2. After this was dried over Na_2SO_4, filtered, and evaporated, a yellow-brown oil remained. This was dissolved in the minimum volume of acetone, and the addition of approximately 5 vol of diethyl ether led to the precipitation of the title compound as light yellow crystals, 0.074 g (71%). Mp ≈ 120 °C dec. IR (NaCl plates, CH_2Cl_2): 3105, 2986, 1766, 1666, 1611, 1570, 1374, 1264, 1195, 1131, 839 cm^{-1}. HRMS−FAB$^+$ (*m*/*z*): M^+ calcd for $C_{25}H_{23}FeO_8$, 507.0742; found, 507.0743.^{1}H NMR (CD_3COCD_3): δ 2.00 (s, 6H), 2.06 (s, 3H), 3.93 (s, 3H), 5.31 (s, 5H), 6.63 (t, J = 6.0 Hz, 1H), 6.71 (dd, J = 6.2, 1.2 Hz, 1H), 6.78 (dt, J = 6.1, 1.2 Hz, 1H), 6.87 (s, 2H), 6.88 (d, J = 6.0 Hz, 1H). ^{13}C NMR (CD_3COCD_3): δ 20.8, 21.0, 57.0, 80.9 (Cp), 84.1, 87.3, 89.0, 89.7, 96.6, 108.0, 118.2, 122.4, 152.2, 165.0, 168.5, 169.4, 188.7.

3-Methoxy-2-(2-methoxybenzoyl) Benzonitrile (12). The complex **9a** (0.100 g, 0.197 mmol) was dissolved in 5 mL of CH_2Cl_2. To the yellow solution was added *n*-Bu_4NCN (0.160 g, 0.594 mmol) dissolved in 1 mL of CH_2Cl_2. **CAUTION! Alkylammonium cyanide compounds are highly toxic and are readily absorbed through the skin.** The solution immediately turned bright red, and it was stirred at rt under Ar for 5 h, after which DDQ (0.096 g, 0.425 mmol) was added. The resulting dark purple solution was stirred for 2 h and then filtered through a short plug of Celite diatomaceous earth. Evaporation of the filtrate gave a dark semisolid from which the title compound could be isolated by flash chromatography (heptane−ethyl acetate, 1:1, R_f = 0.24), as white crystals (0.022 g, 41%). Mp 105−106 °C. IR (KBr): 3060, 3000, 2940, 2220, 1700, 1600, 1550, 1300 cm^{-1}. HRMS-EI (*m*/*z*): M^+ calcd for $C_{16}H_{13}NO_3$, 267.0895; found, 267.0898. ^{1}H NMR ($CDCl_3$): δ 3.61 (s, 3H), 3.72 (s, 3H), 6.92 (dd, J = 8.4, 0.7 Hz, 1H), 7.06 (dt, J = 7.7, 0.9 Hz, 1H), 7.15 (dd, J = 8.5, 0.8 Hz, 1H), 7.30 (dd, J = 7.7, 0.9 Hz, 1H), 7.45 (t, J = 8.1 Hz, 1H), 7.53 (dt, J = 7.3, 1.8 Hz, 1H), 7.83 (dd, J = 7.8, 1.8 Hz, 1H). ^{13}C NMR ($CDCl_3$): δ 55.9, 56.3, 111.0, 112.1, 115.6, 117.2, 121.0, 125.0, 127.1, 130.7, 131.8, 135.3, 136.2, 157.0, 159.8, 192.1.

2-(2-Cyano-6-methoxybenzoyl)-3,5-dimethoxy-carbomethoxybenzene (13). The complex **9b** (0.055 g, 0.092 mmol) was dissolved in 10 mL of CH_2Cl_2. To the yellow solution was added n-Bu_4NCN (0.076 g, 0.285 mmol). **CAUTION! Alkylammonium cyanide compounds are highly toxic and are readily absorbed through the skin.** The solution immediately turned red, and it was stirred at rt under Ar for 2 h, after which DDQ (0.053 g, 0.233 mmol) was added. The resulting dark purple solution was stirred at rt for 4 h and then filtered through a short plug of Celite diatomaceous earth. Evaporation of the filtrate gave a dark semisolid from which the title compound could be isolated by flash chromatography (heptane−ethyl acetate, 1:6, R_f = 0.34), as a slightly red solid, contaminated by an unknown byproduct (0.012 g, 37%). IR (NaCl plates, CH_2Cl_2): 3057, 2945, 2230, 1728, 1668, 1585, 1469, 1265, 1138, 1065 cm^{-1}. HRMS-EI (*m*/*z*): M^+ calcd for $C_{19}H_{17}NO_6$, 355.1056; found, 355.1058. ^{1}H NMR ($CDCl_3$): δ 3.60 (s, 3H), 3.67 (s, 3H), 3.76 (s, 1H), 3.88 (s, 1H), 6.59 (d, J = 2.3 Hz, 1H), 6.98 (d, J = 2.3 Hz, 1H), 7.12 (dd, J = 8.4, 0.9 Hz, 1H), 7.39 (dd, J = 7.6, 1.0 Hz, 1H), 7.49 (dd, J = 8.4, 7.6 Hz, 1H). ^{13}C NMR ($CDCl_3$): δ 52.8, 55.9, 56.5, 56.6, 102.4, 105.7, 116.8, 126.9, 132.3, 158.7, 158.9, 161.8, 167.4, 191.0 (5C, the substituted arene carbons, and the nitrile could not be distinguished from the impurities.)

3-Methoxy-2-(2,4,6-trimethoxybenzoyl) Benzonitrile (14). The complex **9c** (0.267 g, 0.470 mmol) was dissolved in 15 mL of CH_2Cl_2. To the yellow solution was added n-Bu_4NCN (0.356 g, 1.324 mmol). **CAUTION! Alkylammonium cyanide compounds are highly toxic and are readily absorbed through the skin.** The solution immediately turned bright red, and it was stirred at rt under Ar for 5 h, after which DDQ (0.257 g, 1.133 mmol) was added. The resulting dark purple solution was stirred for 13 h and then filtered through a short plug of Celite diatomateous earth. Evaporation of the filtrate gave a dark semisolid from which the title compound could be isolated by flash chromatography, (heptane−ethyl acetate, 1:4, R_f = 0.33), as off-white crystals (0.056 g, 36%). IR (NaCl plates, CH_2Cl_2): 3105, 3014, 2986, 2237, 1666, 1611, 1278, 1259, 1227 cm^{-1}. HRMS-EI (*m*/*z*): M^+ calcd for $C_{18}H_{17}NO_5$, 327.1107; found, 327.1102.^{1}H NMR ($CDCl_3$): δ 3.68 (s, 6H), 3.72 (s, 3H), 3.84 (s, 3H), 6.08 (s, 2H), 7.10 (d, J = 8.3 Hz, 1H), 7.25 (d, J = 7.6 Hz, 1H), 7.38 (t, J = 8.0 Hz, 1H). ^{13}C NMR ($CDCl_3$): δ 55.6, 56.2, 56.7, 91.0, 111.6, 112.7, 116.0, 117.3, 125.3, 130.7, 136.6, 157.4, 161.1, 164.2, 190.5.

3-Methoxy-2-(2,6-dimethoxy-4-isopropylbenzoyl) Benzonitrile (15). The complex **9d** (0.076 g, 0.131 mmol) was dissolved in 5 mL of CH_2Cl_2. To the yellow solution was added n-Bu_4NCN (0.107 g, 0.400 mmol) dissolved in 2 mL of CH_2Cl_2. **CAUTION! Alkylammonium cyanide compounds are highly toxic and are readily absorbed through the skin.** The solution immediately turned bright red, and it was stirred at rt under Ar for 6 h, after which DDQ (0.076 g, 0.335 mmol) was added. The resulting dark purple solution was stirred at rt for 2.5 h and then filtered through a short plug of Celite diatomaceous earth. Evaporation of the filtrate gave a dark semisolid from which the title compound could be isolated by flash chromatography (heptane−ethyl acetate, 1:1, R_f = 0.18), as white crystals (0.032 g, 72%). Mp 147−148 °C. Anal. Calcd for $C_{20}H_{21}NO_4$: C, 70.78; H, 6.24; N 4.13. Found: C, 70.84; H, 6.18; N, 4.09. IR (KBr): 3105, 3032, 2986, 2858, 2830, 2237, 1675, 1602, 1579, 1296, 1250, 1232 cm^{-1}. HRMS-EI (*m*/*z*): M^+ calcd for $C_{20}H_{21}NO_4$, 339.1471; found, 339.1470. ^{1}H NMR ($CDCl_3$): δ 1.25 (d, J = 6.9 Hz, 6H), 2.88 (sep, J = 6.9 Hz, 1H), 3.67 (s, 3H), 3.70 (s, 6H), 6.41 (s, 2H), 7.09 (dd, J = 8.4, 1.0 Hz, 1H), 7.29 (dd, J = 7.7, 1.0 Hz, 1H), 7.40 (dd, J = 8.4, 7.7 Hz, 1H). ^{13}C NMR ($CDCl_3$): δ 23.9, 35.2, 56.2, 56.6, 102.7, 112.0, 116.2, 117.3, 117.4, 125.6, 131.1, 135.8, 154.7, 157.7, 159.1, 191.9.

3-Methoxy-2-(4-acetyl-2,6-dimethoxybenzoyl) Benzonitrile (16). The benzophenone **15** (0.030 g, 0.089 mmol) was dissolved in 4 mL of CCl_4. *N*-bromosuccinimide (0.020 g, 0.113 mmol) and AIBN (0.0040 g, 0.0024 mmol) were added, and the mixture was refluxed under Ar for 2 h. After cooling the mixture to rt, succinimide was filtered off. Evaporation of the solvent provided a brown-white residue, which (by analysis of the crude mixture by ^{1}H NMR) showed no traces of the starting material; instead, signals from monobrominated, dibrominated, and eliminated products (2:1:1) were observed. Therefore, the crude mixture was taken further without purification. The mixture was dissolved in 4 mL of DMF, and after addition of NaOAc (0.013 g, 0.161 mmol) it was heated at 60 °C for 1 h under Ar. After being cooled to rt, the yellow solution was transferred to a separatory funnel and 20 mL of $CHCl_3$ was added. After being washed with 5 × 20 mL of water, the organic phase was dried over Na_2SO_4. After filtration and evaporation, the crude mixture was analyzed by ^{1}H NMR, and was found to contain the expected isopropenyl-substituted benzophenone. Purification by flash chromatography (silica, toluene−ethyl acetate, 4:1) was found to degrade the product, and without further purification, the crude mixture was dissolved in 6 mL of THF−H_2O, 1:1. Osmium tetraoxide (0.010 g, 0.039 mmol) and $NaIO_4$ (0.057 g, 0.266 mmol) were added, and the yellow solution was stirred at rt under Ar for 12 h. THF was then evaporated off and the remaining aqueous solution was extracted with 4 × 5 mL of EtOAc. Drying over Na_2SO_4, filtration, evaporation, and purification by flash chromatography (silica, heptane−ethyl acetate, 1:4, R_f = 0.27) provided the title compound as a slightly yellowish solid, 0.021 g (70% over three steps). HRMS-EI (*m*/*z*): M^+ calcd for $C_{19}H_{17}NO_5$, 339.1107; found, 339.1109. ^{1}H NMR ($CDCl_3$): δ 2.63 (s, 1H), 3.64 (s, 3H), 3.80 (s, 6H), 7.11 (dd, J = 8.5, 0.9 Hz, 1H), 7.14 (s, 2H), 7.35 (dd, J = 7.7, 1.0 Hz, 1H), 7.48 (dd, J = 8.5, 7.7 Hz, 1H). ^{13}C NMR ($CDCl_3$): δ 27.0, 56.5 (3 −OCH_3), 104.4, 112.8, 116.3, 117.4, 123.9, 126.3, 132.2, 133.4, 139.9, 158.3, 158.4, 191.5, 197.5.

4-(2-Cyano-6-methoxybenzoyl)-3,5-dimethoxybenzoic Acid (17). Sodium hydroxide (0.021 g, 0.512 mmol) was dissolved in 0.5 mL of water. The solution was cooled to −5 °C and Br_2 was added. The yellow solution was diluted with

0.5 mL of dioxane. After the solution was stirred at −5 °C for 10 min, a pre-cooled solution of **16** (5 mg, 0.0147 mmol) dissolved in 2 mL of dioxane was added. The temperature was allowed to rise to 5 °C, and the solution was stirred at this temperature for 3 h. A portion of Na_2SO_3 (0.0652 g, 0.517 mmol) dissolved in 1.0 mL of water was added, and stirring was continued at rt for 1 h. After acidification with 10% HCl (aq), the reaction mixture was transferred into a separatory funnel and extracted with 5 × 5 mL of EtOAc. After the mixture was dried over Na_2SO_4, filtered, and evaporated, 2.8 mg of slightly red material was isolated (56%). HRMS-EI (*m*/*z*): $[M+H]^+$ calcd for $C_{18}H_{16}NO_6$, 342.0978; found, 342.0984. ^{1}H NMR ($CDCl_3$): δ 3.65 (s, 3H), 3.80 (s, 6H), 7.32 (s, 2H), 7.39 (dd, J = 8.6, 0.9 Hz, 1H), 7.47 (dd, J = 7.7, 0.9 Hz, 1H), 7.65 (dd, J = 8.5, 7.7 Hz, 1H). ^{13}C NMR ($CDCl_3$): δ 56.7, 56.8, 106.4, 113.4, 117.9, 118.1, 124.9, 127.0, 133.6 (3 C), 133.7, 134.2, 158.8, 167.0, 191.9.

4-(2-Carboxy-6-methoxybenzoyl)-3,5-dimethoxybenzoic Acid (18).[8h] The nitrile **17** (1.2 mg, 3.52 μmol) was dissolved in 0.4 mL of HCl(c)−MeOH, 1:1, and heated to 80 °C, in a sealed vessel, for 11 h. The resulting yellow solution was evaporated to dryness and redissolved in 1 mL of methanol. Lithium hydroxide (6.4 mg, 0.267 mmol) dissolved in 0.5 mL of water was added and the solution was stirred at rt for 30 min. After the solution was acidified with 10% HCl (aq) and evaporated, the residue was dissolved in the minimum volume of acetone, and LiCl was filtered off. Evaporation yielded 0.62 mg (50%) of material with spectroscopic characteristics in agreement with the literature.[11h] MS-electrospray (*m*/*z*): M^+ calcd for $C_{18}H_{17}O_7$, 360.1; found, 360.1. ^{1}H NMR (CD_3SOCD_3): δ 3.56 (s, 6H), 3.64 (s, 6H), 7.17 (s, 2H), 7.18 (d, J = 8.0 Hz, 1H), 7.26 (d, J = 8.0 Hz, 1H), 7.41 (t, J = 8.0 Hz, 1H).

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Supporting Information Available: Detailed description for the preparation of **6b**, **6d**−**j**, **7a**−**j**, **19**, **20**, **21**, **5c**, **5d,** and **5h**, including spectroscopic data. Representative ^{1}H and ^{13}C spectra of **4**, **6j**, **7j**, **8i**, **9d,** and **15**. This material is available free of charge via the Internet at http://pubs.acs.org.

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