ORGANOMETALLIC COMPOUNDS IN ORGANIC SYNTHESIS.

SOME TRICARBONYL(CYCLOHEXADIENYL)IRON CATIONS AND NITROGEN CONTAINING NUCLEOPHILES

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Tricarbonyl(cyclohexadienyl)iron cations react with a range of nucleophiles[1] to give substituted tricarbonyl(cyclohexadiene)iron complexes, but the reactions are often readily reversible if the nucleophile represents a fairly stable anion (OH, OR OAc etc). Aromatic amines have been found to react in good yields to form either nitrogen- or ring-substituted products depending upon the choice of reaction conditions. Thus, tricarbonyl(cyclohexadienyl)iron tetrafluoroborate (1) stirred with aniline, p-toluidine or p-anisidine (2.2 equiv.) in acetonitrile at room temperature gave solely the N-alkylated products (2, R = H, 78%; R = Me, 69%; R = OMe, 64% respectively). The PMR spectrum showed the appropriate methyl (CDCl$_3$:δ 2.23 ppm) or methoxy (CCl$_4$:δ 3.64 ppm) signals and typical aromatic resonances for mono- (2, R = H, CDCl$_3$:δ 6.34 (H2"), 6.80 (H4"), 7.10 (H3")) and p-disubstituted rings (2, R = Me:δ 6.46, 6.98 ppm, J$_{AB}$ = 8.5 Hz; 2, R = OMe:δ 6.33, 6.61 ppm, J$_{AB}$ = 9 Hz) in addition to the usual resonances for the cyclohexadiene ring.
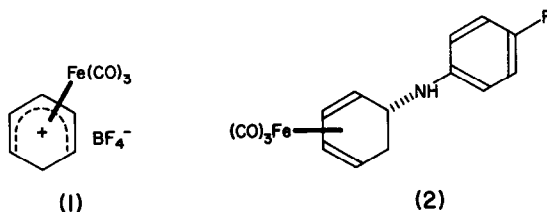
By contrast, addition of the salt in acetonitrile (50 ml), dropwise, to aniline (2.2 equiv.) in acetonitrile (10 ml) at reflux resulted in C-alkylation ortho- and para- to the amine. When the para-position is blocked, ortho- substitution is obtained in high yield, together with a small quantity of disubstituted product, as shown in Table 1. Initially, however, (2, R = OMe) predominated in the product from addition of p-anisidine to (1), but rapidly decreased in concentration in favour of (4, R^1 = OMe, R^2 = R^3 = H) as the solution was heated, presumably through an acid catalysed reversal to reform the salt (1). This suggestion received support from the observation that (2, R = OMe) briefly heated in acetonitrile in the presence of acetic acid gives (4, R$_1$ = OMe, R$_2$ = R$_3$ = H) but is unchanged when heated alone or with p-anisidine. This result suggests that (4, R$_1$ = OMe, R$_2$ = R$_3$ = H) is not formed through an intramolecular migration. Unsymmetrical cations (3, R$_2$ = Me, OMe,

R_3 = H) exhibited good regioselectivity and only 5-substituted addition products were obtained. (3, R_2 = H, R_3 = Me) gave (4, $R_1 = R_3$ = Me, R_2 = H) as expected, when heated with p-toluidine. The yields obtained are satisfactory (Table 1) and NMR assignments are given in Table 2 for (a), mono- and (b), di-substituted products.

Table 1.
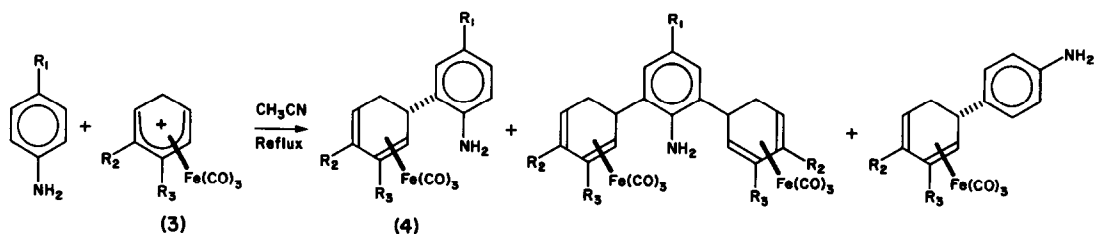
	R_1	R_2	R_3			
(BF_4^-)	H	H	H	39%	Trace	29%
(PF_6^-)	H	OMe	H	41%	0	27%
(BF_4^-)	OMe	H	H	45%	6% *	−
(BF_4^-)	Me	H	H	67%	22% *	−
(PF_6^-)	Me	OMe	H	62%	7% *	−
(PF_6^-)	Me	Me	H	52%	12% *	−
(PF_6^-)	Me	H	Me	72%	4% *	−

* Based on (3)

Table 2. PMR data in p.p.m. (δ) : (a)

R_1	R_2	R_3	Solv.	R_1	R_2	R_3	H1	H2	H3	H4	H5'	H6	H6'	NH_2	H3''	H4''	H5''	H6''
H	H	H	CCl4	−	−	−	3.11	5.42	5.42	3.11	3.32	1.53	2.32	3.20	6.97	6.57	6.68	6.40
OMe	H	H	CDCl3	3.73	−	−	3.17	5.51	5.51	3.17	3.41	1.58	2.39	3.29	Ar: 6.56,6.73			
Me	H	H	CCl4	2.18	−	−	3.12	5.45	5.45	3.12	3.31	1.44	2.30	3.22	6.71	−	6.66	6.32
H	OMe	H	CCl4	−	3.61	−	3.34	−	5.17	2.68	3.10	1.65	2.33	3.34	6.98	6.59	6.85	6.41
Me	OMe	H	CCl4	2.18	3.62	−	3.36	−	5.18	2.68	3.10	1.62	2.31	3.20	6.73	−	6.65	6.31
Me	Me	H	CCl4	2.17	2.13	−	3.1	−	5.35	2.91	3.20	1.52	2.31	3.20	6.70	−	6.65	6.31
Me	H	Me	CCl4	2.18	−	2.18	2.98	5.40	−	3.12	3.34	1.50	2.27	3.27	6.63	−	6.69	6.34

(b)				R_1	R_2	R_3	H1	H2	H3	H4	H5'	H6	H6'	NH_2	H3''
OMe	H	H	CCl4	3.66	−	−	3.1	5.48	5.48	3.10	3.34	1.50	2.32	3.20	6.43
Me	H	H	CCl4	2.17	−	−	3.10	5.46	5.46	3.10	3.30	1.49	2.30	3.24	6.65
Me	OMe	H	CCl4	2.19	3.65	−	3.38	−	5.22	2.68	3.10	1.60	2.33	3.22	6.61
Me	Me	H	CCl4	2.18	2.18	−	3.12	−	5.42	2.94	3.24	1.50	2.34	3.24	6.59
Me	H	Me	CCl4	2.19	−	2.17	2.95	5.37	−	3.08	3.32	1.43	2.25	3.27	6.53

H': on the same face as the metal

H'': on the aromatic ring

The presence of a strongly electron withdrawing substituent in the aryl ring inhibits nuclear substitution and (1) together with 4-nitroaniline yielded only N-alkylated product (2, R = NO_2), mp 142-144°, under a variety of conditions. Activation of the ring by 3-methoxy or 3-amino substituents, on the other hand, resulted in C-alkylation even at room temperature. Addition of the amines to (1) in acetonitrile required 1.5 equivalents to bring the reaction to completion, and only disubstituted products were obtained. (One equivalent of the amine is protonated by the fluoroboric acid produced during the reaction.) Substitution occurred at C4" and C6" to give (5, R = OMe), mp 98-99°, (PMR: CCl_4, δ 1.58 (H6), 2.33 (H6'), 3.15 (H1, H4), 3.36 (NH_2), 3.57 (H5'), 3.67 (OMe), 5.50 (H2, H3), 5.88 (H2"), 6.76 (H5")), 62%, and (5, R = NH_2), mp 136-138°, (PMR: CCl_4, δ 1.54 (H6), 2.29 (H6'), 3.2 (NH_2, H5', H1, H4), 5.50 (H2, H3), 5.64 (H2"), 6.65 (H5")), 72%.

The Fe(CO)$_3$ group was readily removed from (6, R_1 = R_2 = Me), mp 118-120°, by warming for 2 mins. with an excess of ferric chloride in aq.acetic acid (40%) to generate the diene (7, R_1 = R_2 = Me), characterised as the 2,4-dinitrobenzylidene derivative, mp 155-157°. An attempt to remove the Fe(CO)$_3$ group by addition of iodine (3 equiv.) to the amine (6, R_1 = R_2 = Me) in pyridine, followed after 30 min. by sodium hydrosulphite and work-up with aq.citric acid (5%) gave 2,3-dimethylcarbazole (8, R_1 = R_2 = Me), mp 250-252°, (lit.[2] 251-253°), in 32% yield. Similarly, (6, R_1 = Me, R_2 = H) gave 3-methylcarbazole (8, R_1 = Me, R_2 = H), mp 206-207°, (lit.[3] 208°), 62%.

Amides, although relatively feeble nucleophiles, were also found to form stable adducts with (1). Acylaminocyclohexadiene derivatives were obtained by either dissolving the cation (1) in an excess of the amide and heating for 10 min., or by adding (1) to the amide dissolved in hexamethylphosphoramide at 90° for 2 min. Primary amides such as formamide, product mp 113-115°, and methyl carbamate, mp 125-126°, as well as the secondary amide, 2-pyrrolidone, mp 153-154°, reacted readily. Thiourea, however, formed the S-linked product (9), mp 170° (dec).

Although imides themselves did not react under these conditions, the potassium salt of phthalimide in acetonitrile containing (3, R_2 = OMe, R_3 = H), at room temperature over 1 hr., gave (10), mp 128-130°, in high yield. The Fe(CO)$_3$ group was removed from this compound without difficulty by warming with an excess of trimethylamine-N-oxide, dihydrate (cf. Ref. 4) in demethyl acetamide at 90° for 10 mins. The iron-free diene (mp 114-116°) formed an adduct, mp 210-212°, with tetracyanoethylene when refluxed together in benzene for 30 min.

(9)   (10)
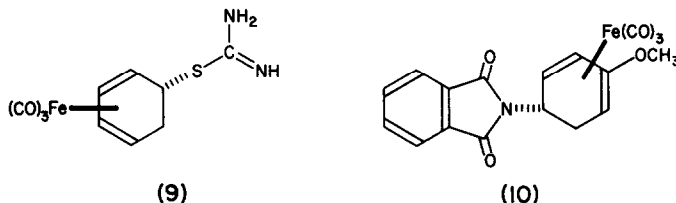
The structures of the products are supported by analytical, PMR, i.r. and mass spectral data which agree with accepted standards and interpretations. Disubstituted aromatic products are characterised as a mixture of diastereoisomers. The configurations shown are the result of attack opposite to Fe(CO)$_3$, assumed by analogy with other reactions of this type.

References

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