nmr δ 8.41 (m), 7.76 (m), 7.21 (m) (aromatic signals), 5.15 (b, OH), 3.56 (d, $J = 5$ Hz, CH_2O), 2.92 (d, $J = 8$ Hz, H_a), 2.11 (s, CH_3), 3.19 (m, H_f), 2.00 ppm (m, 4 H).

Anal. Calcd for $C_{11}H_{16}N_2O$: C, 68.72; H, 8.39; N, 14.57. Found: C, 68.72; H, 8.17; N, 14.46.

trans-**3′-Methylnicotine (2a).**—The above hydroxymethyl compound **8** (1.81 g, 9.41 mmol) in pyridine (40 ml) was treated with tosyl chloride (1.79 g, 9.40 mmol) at 1° for 21 hr. The solution was then added to ice-cold 5% K_2CO_3 (100 ml) and the mixture extracted rapidly with $CHCl_3$ (four 200-ml portions). After drying ($MgSO_4$), the $CHCl_3$ and pyridine were removed *in vacuo* to yield a reddish-brown oil (3.70 g) which was dissolved in Et_2O (200 ml) and treated with $LiAlH_4$ (0.35 g, 9.4 mmol) at room temperature for 12 hr. The reaction mixture was decomposed with H_2O (0.35 ml), 15% NaOH (0.35 ml), and finally H_2O (1.05 ml). After filtering, drying ($MgSO_4$), and removing solvent, the residue (1.59 g) was chromatographed on alumina. Elution with $CHCl_3$ gave the 3′-methylnicotine (**2a**) (0.88 g, 53%) which was purified by short-path distillation: bp 40–42° (1.0 mm). The homogeneity of the distillate was established by observing only one peak on glpc (retention time 245 sec, $^1/_8$ in. × 6 ft, 3% OV 17 on acid-washed Chromosorb W, 100–120 mesh, 146° column temperature, N_2 flow 26 ml/min).

Mass spectrum. Calcd for $C_{11}H_{16}N_2$: *m/e* 176.1313. Found: 176.1299. Calcd for $C_6H_{12}N$ (1,3-dimethyl-1-pyrrolinium fragment): 98.0970. Found: 98.0966. Mass fragments: *m/e* 176 (43), 175 (14), 134 (100), 119 (14), 98 (86).

The dipicrate was prepared for analysis, mp 199–200°.

Anal. Calcd for $C_{23}H_{22}N_8O_{14}$: C, 43.54; H, 3.50; N, 17.66. Found: C, 43.47; H, 3.48; N, 17.54.

Registry No.—**2a,** 33223-98-2; **2a** dipicrate, 33223-99-3; **6,** 16273-54-4; **7,** 33224-01-0; **8,** 33224-02-1; **9,** 33224-03-2.

Ferrocenophanes. An Improved Synthesis of 3-Phenyl[5]ferrocenophane-1,5-dione Involving a Reverse Aldol Condensation[1]

JACK A. WINSTEAD

The Frank J. Seiler Research Laboratory, Air Force Systems Command, U. S. Air Force Academy, Colorado 80840

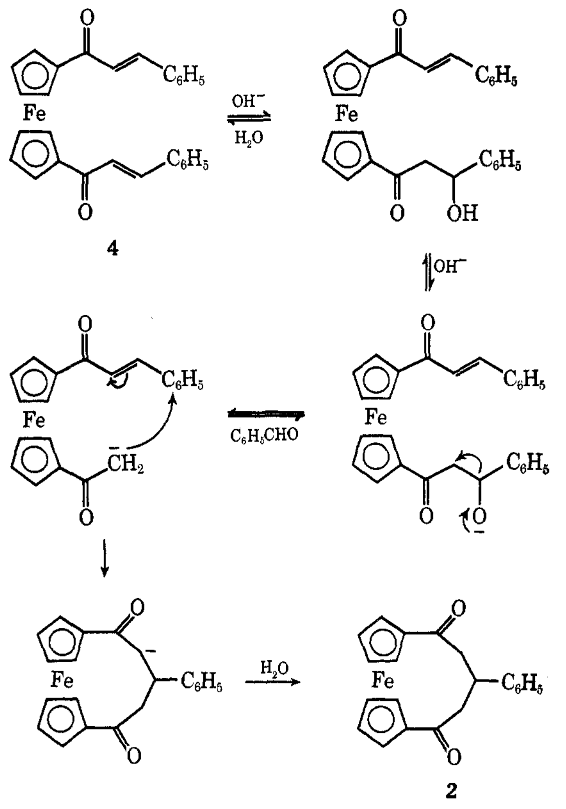
Received July 12, 1971

It has been reported[2] that 1,1′-diacetylferrocene (**1**) and benzaldehyde undergo an alkali-catalyzed aldol type condensation to form mono- and dibenzaldehyde derivatives and a yellow product. One of several suggested structures for the yellow product was 3-phenyl-[5]ferrocenophane-1,5-dione (**2**). This structure was later confirmed by Furdik, *et al.*[3] Barr and Watts[4] have synthesized **2** from acetylferrocene by first preparing 1-acetyl-1′-cinnamoylferrocene (**3**) (80% yield) and then by cyclizing the product under alkaline conditions to **2** (69% yield). This results in an overall yield of 55% for the two reactions.

We have recently synthesized **2** in two steps starting with ferrocene. Ferrocene is first dicinnamoylated by the Friedel–Crafts reaction to yield 1,1′-dicinnamoylferrocene (**4**), which is treated with base to yield **2**. The overall yield for the two steps was 73%. This yield is considerably higher than the previously reported yield of 55% and starts with the readily available ferrocene rather than acetylferrocene.

Nielson and Houlihan[5] discussed a number of important syntheses involving a Michael condensation followed by an intramolecular aldol condensation. The synthesis of **2** appears to be a unique example of a reverse aldol condensation step in a synthesis followed by an intramolecular Michael addition. A probable mechanism for this synthesis involves a base-catalyzed reverse aldol type condensation (reverse Claisen–Schmidt) to form the carbanion which is followed by internal Michael addition to form the heteroannular bridge (Scheme I).

SCHEME I



Since **4** is a symmetrical molecule, base attack on either cinnamoyl group leads to the carbanion intermediate after a reverse aldol condensation. In the case of base treatment of **3**, attack on the acetyl group generates the necessary carbanion for ring closure to yield **2**. However, if the cinnamoyl group is attacked, a reverse aldol condensation would lead to the carbanion of **1** which would not lead to the product. This could account for the smaller yield starting with **3**.

Experimental Section

Infrared spectra were recorded as Nujol mulls on a Beckman IR-4 and were calibrated against polystyrene film; nmr spectra were determined in deuteriochloroform on a Varian A-60 using TMS as an internal standard. Analyses were performed at Huffman Laboratories, Inc., Wheatridge, Colo. All melting points were determined using a Reichert Austria melting point apparatus and are uncorrected.

---

[1] The views expressed herein are those of the author and do not necessarily reflect the views of the United States Air Force or the Department of Defense.

[2] T. A. Mashburn, Jr., C. E. Cain, and C. R. Hauser, *J. Org. Chem.*, **25**, 1982 (1960).

[3] M. Furdik, S. Toma, J. Suchy, and P. Elecko, *Chem. Zvesti*, **15**, 45 (1961); *Chem. Abstr.*, **55**, 18692*e* (1961).

[4] T. H. Barr and W. E. Watts, *Tetrahedron*, **24**, 3219 (1968).

[5] A. T. Nielson and W. J. Houlihan, *Org. React.*, **16**, 47 (1968).

1,1′-Dicinnamoylferrocene (2).—A solution of cinnamoyl chloride (8.25 g, 0.049 mol) and $AlCl_3$ (6.6 g, 0.049 mol) in dry CH_2Cl_2 (75 ml) was added slowly to a solution of ferrocene (4 g, 0.022 mol) in dry CH_2Cl_2 (75 ml). The mixture was stirred for 4 hr at 25° in a N_2 atmosphere, then poured into 300 ml of ice-water. The organic phase was separated and combined with the CH_2Cl_2 extracts of the aqueous phase. The combined organic phases were washed with water, dried with $MgSO_4$, and taken to dryness. The residue was dissolved in a minimum volume of benzene with heating and allowed to crystallize. After removal of crystalline **4** (7.9 g) the solution was reduced to a small volume and chromatographed on neutral alumina. Petroleum ether (bp 20–40°)-diethyl ether (3:2) eluted a small band of ferrocene and a second small band of cinnamoylferrocene. Methylene chloride eluted an additional 0.6 g of **4**. The 8.5 g of crystalline (red needles) product represents an 88% yield, mp 180.5–182° (lit.[2] mp 208–210°), ir 6.01 μ, nmr τ 2.06–3.07 (m, 14 H, vinyl and Ph protons), 5.06, 5.39 (2 t, 8 H, cyclopentadienyl protons).

Anal. Calcd for $C_{28}H_{22}O_2Fe$: C, 75.35; H, 4.97; Fe, 12.51. Found: C, 75.25; H, 5.01; Fe, 12.85.

Due to the discrepancy in melting point, **4** was synthesized from **1** according to the directions of Mashburn, *et al.*,[2] which after repeated recrystallizations from ethanol-water melted at 180.5–182°. Ir and nmr spectra of this compound were also identical with those of **4** synthesized by Friedel-Crafts dicinnamoylation of ferrocene.

3-Phenyl[5]ferrocenophane-1,5-dione (2).—Aqueous 15% NaOH solution (100 ml) was slowly added to a solution of **4** (5 g, 0.011 mol) in 500 ml of 95% ethanol and 150 ml of THF. The mixture was stirred at 25° in a nitrogen atmosphere for 65 hr and diluted with 800 ml of water. The suspension was extracted with $CHCl_3$. The extract was then dried with $MgSO_4$, concentrated, and chromatographed on neutral alumina. Only one band developed, which was eluted with CH_2Cl_2-$CHCl_3$ (1:1). Crystallization from ethanol yielded 3.7 g of yellow feathers (yield 92%), mp >300° (lit.[2-4] mp >300°), ir 6.03 μ (lit.[4] 6.03 μ).

Anal. Calcd for $C_{21}H_{18}O_2Fe$: C, 70.41; H, 5.06; Fe, 15.59. Found: C, 70.18; H, 5.04; Fe, 15.64.

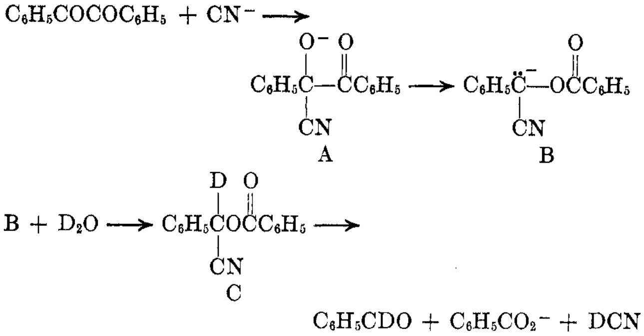
A Convenient Synthesis of Benzaldehyde-*formyl-d* from Benzil[1]

ALBERT W. BURGSTAHLER, DONALD E. WALKER, JR.,
JOHN P. KUEBRICH, AND RICHARD L. SCHOWEN*[2]

*Department of Chemistry, The University of Kansas,
Lawrence, Kansas 66044*

Received November 4, 1971

Although various methods[3] are now available for the synthesis of deuterio and tritio aldehydes, practically all of them involve multistep procedures, costly reagents, or extended reaction periods. In seeking a simple, rapid route to benzaldehyde-*formyl-d*, we have found that the facile cleavage of benzil by cyanide ion in the presence of D_2O, occurring apparently through adduct A and its rearrangement products B and C,[4] provides a convenient source of this compound.



$$C_6H_5COCOC_6H_5 + CN^- \longrightarrow \underset{\text{A}}{C_6H_5\overset{O^-}{\overset{|}{C}}(\underset{CN}{})\!-\!\overset{O}{\overset{\|}{C}}C_6H_5} \longrightarrow \underset{\text{B}}{C_6H_5\ddot{C}^-(\underset{CN}{})\!-\!O\overset{O}{\overset{\|}{C}}C_6H_5}$$

$$B + D_2O \longrightarrow \underset{\text{C}}{C_6H_5\overset{D}{\overset{|}{\underset{\underset{CN}{|}}{C}}}O\overset{O}{\overset{\|}{C}}C_6H_5} \longrightarrow C_6H_5CDO + C_6H_5CO_2^- + DCN$$

When dry potassium cyanide is added at room temperature to 1 equiv of benzil in dioxane containing 10 equiv of D_2O, the yellow α-diketone color gradually disappears. After dilution of the mixture with ordinary water, extraction with ether, and washing of the ether extract, benzaldehyde-*formyl-d* of 98% isotopic purity (by nmr analysis) can be recovered in 55–60% yield by distillation. The remainder of the product consists of an equivalent amount of benzoic acid (separated in the extraction and washing), unchanged benzil, and a mixture of what appears to be α-deuteriobenzoin and its benzoate ester.[4] The benzoin derivatives are evidently formed not by the benzoin condensation but, as shown recently,[4] through trapping of carbanion B by deuteriobenzaldehyde, even though the latter must compete with an appreciable excess of D_2O. (With the use of less than 10 equiv of D_2O more by-products are formed, and the yield of aldehyde is diminished.) When conducted in dioxane-H_2O in the presence of tritium oxide the reaction furnishes benzaldehyde containing benzaldehyde-*formyl-t*.

Although cyanide ion is theoretically required only in catalytic amounts, the reaction is erratic and the yield of aldehyde is lower when less than a full molar equivalent of cyanide is used. In addition, the disappearance of the yellow diketone color occurs much more slowly when less cyanide is used, even when potassium carbonate is added to prevent its loss as DCN. Use of sodium cyanide in place of potassium cyanide is unsatisfactory because of the formation of difficultly soluble salts during the initial stages of the reaction.

Experimental Section

Benzaldehyde-*formyl-d*.—By means of a syringe, 10 ml of D_2O (99.87%, Bio-Rad Laboratories) was added to a magnetically stirred solution of 10.5 g (0.050 mol) of benzil (recrystallized from carbon tetrachloride[5]) in 25 ml of dry 1,4-dioxane under a dry, inert atmosphere (argon or nitrogen) at 20–25°. To the resulting fine suspension of benzil were added, with rapid stirring, at 2-min intervals, four 1-g portions of reagent-grade potassium cyanide (previously dried at 125°). After the second addition of cyanide the mixture became homogeneous, and the yellow color disappeared within 2 min after the last addition. Stirring was continued for 10 min as potassium benzoate gradually precipitated. The mixture was then diluted with 100 ml of distilled water and extracted with two 50-ml portions of ether. The combined ether extracts were washed with 50 ml of 5% sodium carbonate solution, 100 ml of water, and finally with 50 ml of saturated sodium chloride solution. After drying for 2 min over $MgSO_4$ the ether solution was concentrated in a rotary evaporator under aspirator vacuum on a water bath. Distillation of the light yellow residue (5.5 ml) gave, in separate runs, 2.95 to 3.2 g (55–60%) of benzaldehyde-*formyl-d*, bp 84–86° (30 mm). By nmr analysis this contained 0.98 atom of deuterium per molecule. Crystallization of the still-pot residue

---

(1) This research was supported in part by the National Science Foundation and the National Institutes of Health.

(2) Holder of a Research Career Development Award of the National Institute of General Medical Sciences.

(3) *E.g.*, D. Nasipuri, C. K. Gosh, and R. J. L. Martin, *J. Org. Chem.*, **35**, 657 (1970) [citing D. J. Bennett, G. W. Kirby, and V. A. Mess, *Chem. Commun.*, 218 (1967)]; A. I. Meyers, A. Nabeya, H. W. Adickes, and I. R. Politzer, *J. Amer. Chem. Soc.*, **91**, 763 (1969); T. Axenrod, L. Loew, and P. S. Pregosin, *J. Org. Chem.*, **33**, 1274 (1968); J. Cymerman Craig and L. R. Kray, *ibid.*, **33**, 871 (1968); R. A. Olafson and D. M. Zimmerman, *J. Amer. Chem. Soc.*, **89**, 5057 (1967); D. Seebach, B. W. Erickson, and G. Singh, *J. Org. Chem.*, **31**, 4303 (1966); V. E. Althouse, D. M. Feigl, W. A. Sanderson, and H. S. Mosher, *J. Amer. Chem. Soc.*, **88**, 3595 (1966).

(4) For a recent study and references to earlier work, see J. P. Kuebrich and R. L. Schowen, *J. Amer. Chem. Soc.*, **93**, 1220 (1971).

(5) H. T. Clarke and E. E. Dreger, "Organic Syntheses," Collect. Vol. I, 2nd ed, Wiley, New York, N. Y., 1941, p 87.