

1,1';3,3';4,5;4',5'-TETRAKIS-(TRIMETHYLENE)-FERROCENE

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A recent publication (1) from one of these laboratories described the preparation of 1,1';3,3';4,5-tris-(trimethylene)-ferrocene (VII) by the route shown in FIG. 1, and its acetylation to a mixture of IX, X, and XI.* We now wish to report the preparation of 1,1';3,3';4,5;4',5'-tetrakis-(trimethylene)-ferrocene (XIII) via the reaction sequence (FIG. 2) employed in the earlier work (1).

4'-Acetyl-1,1';3,3';4,5-tris-(trimethylene)-ferrocene (IX) (1) was treated with sodium hydride and diethyl carbonate (step 3), the resulting β -keto ester was hydrogenolyzed to the ethyl 4'-propionate (step 4), which was hydrolyzed (step 5) to the 4'-propionic acid. The latter was cyclized with trifluoroacetic anhydride in carbon tetrachloride (step 6) to 4',5'-(α -ketotrimethylene)-1,1';3,3';4,5-tris-(trimethylene)-ferrocene (XII) [Anal. Found: C, 73.28; H, 6.89]. The homoannular nature of the ketone is indicated (1) by the position of its carbonyl band at 1691 cm^{-1} (carbon tetrachloride) and its ultraviolet extinction coefficient (ϵ 15,500 at λ_{max} 232 m μ and ϵ 6700 at λ_{max} 271 m μ); its n.m.r. spectrum, with two ring proton singlets at τ 6.77 (benzene), is in accord with structure XII. The ketone

* Compounds II, IV, V, VI, IX, XII, XV, and XVIII were obtained as racemic mixtures; only one enantiomorph is shown.

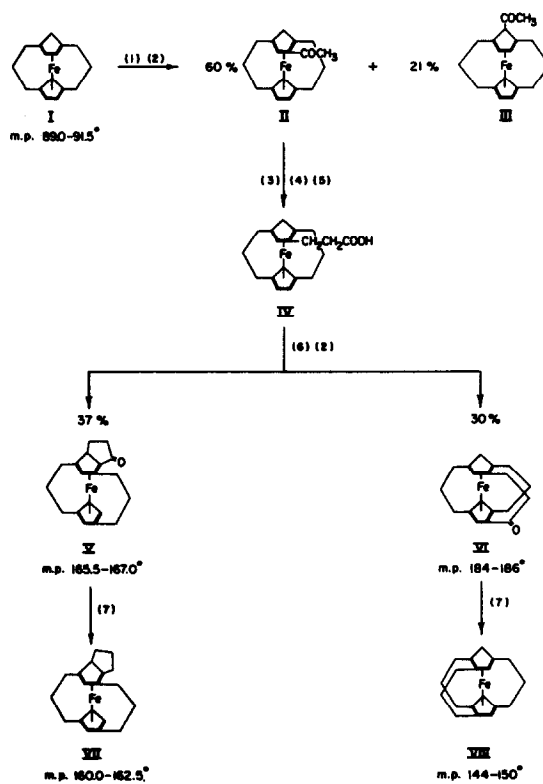


FIG. 1

Bridged and homoannularly cyclized products (Ref. 1) from 1,1',3,3'-bis-(trimethylene)-ferrocene-4-propionic acid (IV); numbered steps: (1) $(\text{CH}_3\text{CO})_2\text{O}$, AlCl_3 ; (2) chromatographic separation; (3) NaH , $\text{CO}(\text{OC}_2\text{H}_5)_2$; (4) H_2 , $\text{P}+\text{O}_2$, CH_3COOH ; (5) NaOH then H_3PO_4 ; (6) $(\text{CF}_3\text{CO})_2\text{O}$; (7) $\text{IAlH}_4\text{-AlCl}_3$.

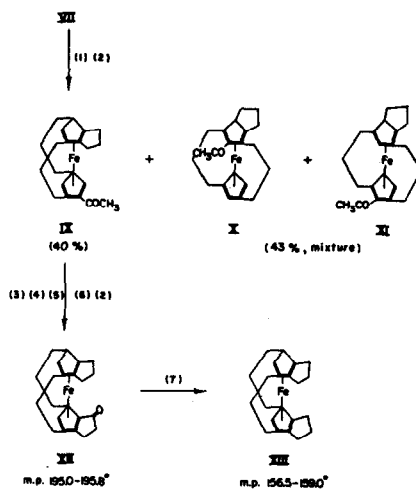


FIG. 2

Synthetic route to 1,1';3,3';4,5;4',5'-tetrakis-(trimethylene)-ferrocene (**XIII**); numbered steps same as in FIG. 1.

was reduced with lithium aluminum hydride-aluminum chloride (step 7) to 1,1';3,3';4,5;4',5'-tetrakis-(trimethylene)-ferrocene (**XIII**) [Anal. Found: C, 76.44; H, 7.71; Mol. wt., 346 (mass spec.)]. The symmetrical nature of **XIII** is indicated by its n.m.r. spectrum, which contains a two-proton singlet in the ring proton region, at τ 6.52 in benzene solution (at

τ 6.42 in chloroform).

In another recent study of multicyclic ferrocenes Schlögl and Peterlik (2) reported the preparation (FIG. 3) of a tetrakis-(trimethylene)-ferrocene (G), to which they assigned the structure 1,1';2,2';3,3';4,4'-tetrakis-(trimethylene)-ferrocene (XIV). Their synthesis of G proceeded from I, via the intermediates XV, IV, A, C, E, and F.

However, the structure (XIV) assigned to G by these authors cannot be correct, as may be seen by comparing the routes and melting points of FIGS. 1 and 2 vs. 3. These authors' cyclization of IV* gave a ketone (A) of m.p. 159-160° as the favored product and a ketone (B) of m.p. 185-188° as the less favored isomer. The close correspondence in melting points and chromatographic behavior [VI moves faster than V (1), and B faster than A (2)] shows A to be V [not VI, as it was assigned (2)]** and B to be VI.*** All

* The structure of XV is not in doubt. We have repeated the formylation procedure of Schlögl and Peterlik and have isolated XV, m.p. 86-89° after sublimation [reported (2) 88-89°]. Its structure is demonstrated most clearly by its n.m.r. spectrum (carbon tetrachloride), which contains an aldehydic proton at τ 0.31 and whose ring proton region contains a low field proton at τ 5.60 (H-5) and generally resembles that of II (1) but not that of III (1).

** In addition to the mistake made in assigning heteroannular structures to the homoannular products V and VII, there are unfortunate and confusing typographical errors in most of the formulas on p. 1333 in Ref. 2b and on p. 576 in Ref. 2a. For example, the present compounds I, XV, and IV (compounds numbered XI, XII, and XIV, respectively, in Ref. 2b) are pictured there as derivatives of 1,1';2,2'-bis-(trimethylene)-ferrocene, even though they are correctly referred to as derivatives of the 1,1';3,3'-isomer in the Experimental Part, and though compound I (XI in Ref. 2b) had earlier been assigned the correct structure (3). Similarly, in Ref. 2a the ketones A and B of FIG. 3 (numbered Va and Vb in Ref. 2a), their reduction products C and D, and all further compounds from A and C, are pictured again as having been derived from 1,1';2,2'-bis-(trimethylene)-ferrocene, though on an earlier page of the same article the starting material was clearly given as 1,1';3,3'-bis-(trimethylene)-ferrocene (I in the present report, III in Ref. 2a).

*** The structure of ketone B (VI) was not assigned in Ref. 2b. However, in the preliminary report (Ref. 2a) it was pictured on p. 576 as 3,3'-(α -ketotrimethylene)-1,1';2,2'-bis-(trimethylene)-ferrocene. This is apparently another typographical error, as that structure would be impossible starting from 1,1';3,3'-bis-(trimethylene)-ferrocene; it is not clear what structure was intended. The structures assigned in our earlier paper (1) to ketones V and VI rest firmly on the ultraviolet spectra of V and VI and on the acetylation products of VII and VIII derived, respectively, from them.

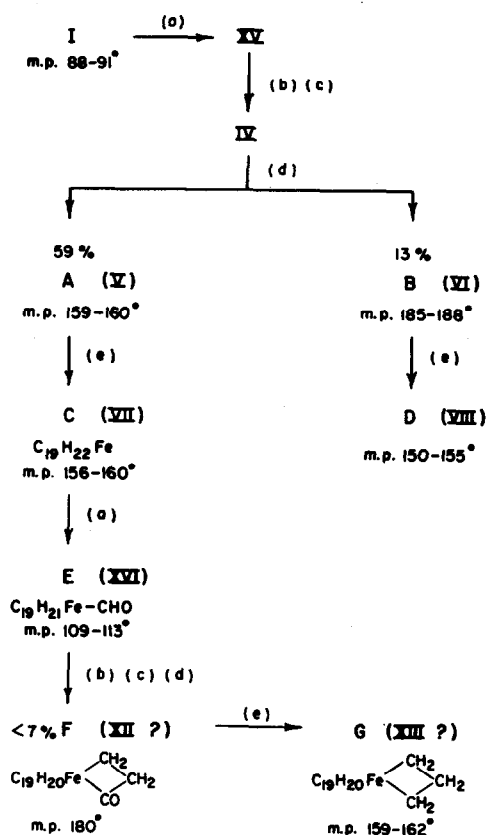


FIG. 3

Bridged and homoannularly cyclised products (Ref. 2) from 1,1';3,3'-bis-(trimethylene)-ferrocene-4-propionic acid (IV); lettered steps: (a) $\text{C}_6\text{H}_5\text{N}(\text{CH}_3)\text{CHO}$, POCl_3 ; (b) $\text{CH}_2(\text{COOH})_2$, $\text{C}_2\text{H}_5\text{N}$, $\text{C}_2\text{H}_{11}\text{N}$; (c) $\text{P}+\text{O}_2$, H_2 , CH_3COOH ; (d) $(\text{CF}_3\text{CO})_2\text{O}$; (e) $\text{LiAlH}_4-\text{AlCl}_3$.

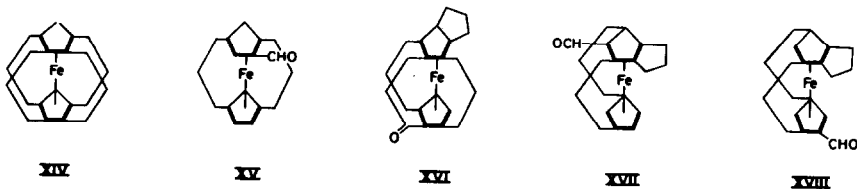
further operations, to give C, E, F, and G, were then carried out starting from the lower-melting ketone (A = V); hence, compounds C, E, F and G must all contain at least one homoannular ring and the final product cannot be XIV.

Though the above considerations indicate what compounds F and G are not, they do not establish what they are. The rather close agreement in melting points suggests that F and G are probably XII and XIII, respectively.* The only isomer of F possible, starting from VII, would be 2,2'-(α -ketotrimethylene)-1,1';3,3';4,5-tris-(trimethylene)-ferrocene (XVI). On steric grounds this should be very difficult to form, as evidenced by the failures of 1,1';3,3'-bis-(trimethylene)-ferrocene-2-propionic acid (1) and of 1,1';2,2';4,4'-tris-(trimethylene)-ferrocene-3-propionic acid (4) to cyclize heteroannularly between two bridges.

In the present investigation we have formylated VII and have isolated after very careful chromatography two formyl derivatives, XVII and XVIII, in the approximate ratio of 3 to 1, respectively.** After repeated

* The melting points of XII and XIII before sublimation were 186-187.5° and 154-156°, respectively. Minor impurities thus seem to depress the m.p. of XII considerably. [The m.p. reported for F was 180° (2b), 175-180° (2a)].

** The formation of a mixture of isomeric formyl derivatives from VII is surprising, since earlier authors (2,3) have reported only a single product from the Wilsmeier reaction. In agreement with their report (2), we also find only one isomer, XV, from the formylation of I.



sublimation the major product, XVII, has m.p. 124.5-127^o, [Anal. Found: C, 71.83; H, 7.00], and the minor product, XVIII, m.p. 107-109.5^o [Anal. Found: C, 72.11; H, 6.83]. The structure of XVII is established by its n.m.r. spectrum (carbon tetrachloride), with a two-proton doublet ($J = 1.4$ c.p.s.) at τ 6.62 and a one-proton triplet at τ 6.27 in the ring proton region; the doublet and triplet appear at τ 6.78 and 6.30, respectively, in benzene. Similarly, the structure of XVIII is assigned from its n.m.r. spectrum (carbon tetrachloride), with ring proton peaks at τ 5.92 and τ 6.01 (H-5' and H-2' doublets, $J = 1.4$ c.p.s.), and at τ 6.50 (H-2 singlet); these peaks occur in benzene solution at τ 5.98, 6.29, and 6.74, respectively. The earlier authors (2) reported only one isomer from formylation of VII; its m.p. (109-113^o) agrees reasonably well with that of XVIII. Either pure XVIII or the presence of XVIII in a mixture with XVII would account well for the isolation of 7% of XII from the reaction sequence of FIG. 3.

REFERENCES

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- (2) K. Schlögl and M. Peterlik, (a) Tetrahedron Letters, 573 (1962); (b) Monatsh., 93, 1328 (1962).
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- (4) D. E. Bublitz, unpublished.