Tetrahedron Letters,Vol.24,No.28,pp 2803-2806,1983 0040-4039/83 \$3.00 + .00
Printed in Great Britain

NUCLEOPHILIC RING OPENING OF DIETHYL 1,1-CYCLOPROPANEDICARBOXYLATE USING $Na_2Fe(CO)_4\cdot3/2$ DIOXANE

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Abstract: Diethyl 1,1-cyclopropanedicarboxylate undergoes nucleophilic ring opening with $Na_2Fe(CO)_4\cdot3/2$ dioxane under CO at room temperature to produce a variety of carbonylated products.

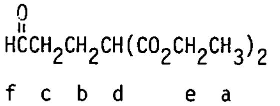
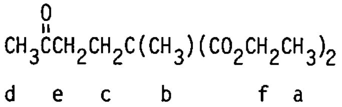
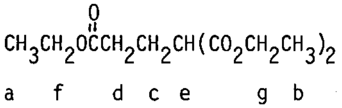
Transition metal promoted rearrangements of small ring organic compounds continue to receive intense examination.[1] The common mechanistic feature of these reactions appears to be insertion of a coordinatively unsaturated transition metal electrophile into a carbon-carbon bond.[1-3] Such reactions have been exploited in the conversion of cyclopropanes to olefins and for the formation of isolable metallocyclic compounds.[1] In sharp contrast to the extensive study given such electrophilic ring openings, no investigation of ring openings promoted by transition metal nucleophiles has been reported.[4] This is true despite the fact that anionic organometals such as the carbonyl anions of molybdenum, manganese, iron and cobalt have been shown to be excellent nucleophiles,[5,6] displaying a range in relative nucleophilicities of 10^{10}. Their reactions with typical organic halides and tosylates display all the characteristics of S_N2 behavior, producing new organometallic complexes containing alkyl ligands which have undergone complete stereochemical inversion.[5,6] The great synthetic advantage of these organometallic nucleophiles results from the fact that their alkyl complexes undergo a wide variety of intramolecular rearrangements, the most important of which is alkyl migration to a cis-carbonyl without loss of stereochemistry.[5,6] The resulting acyl complex, which is more stable than its parent alkyl complex, can be cleaved by a variety of reagents to produce an aldehyde, an acid, esters or ketones.[6,7]

We wish to report (1) that $Na_2Fe(CO)_4\cdot3/2$ Dioxane is an effective reagent for nucleophilic ring opening of diethyl 1,1-cyclopropanedicarboxylate under very mild conditions and (2) the potential of this ring opening for the synthesis of a variety of carbonylated products.

In a typical synthesis $Na_2Fe(CO)_4\cdot3/2$ Dioxane (1.60 g, 4.62 mmol) was weighed into a 100 ml, 3-necked round bottom flask under the N_2 atmosphere of a glove bag. The flask was transferred to an exhaust hood where it was purged with CO. The iron nucleophile was then dissolved in 60 cc of freshly distilled THF (LAH under N_2). The solution was stirred under CO for 5 min, after which diethyl 1,1-cyclopropanedicarboxylate (0.735 g, 3.95 mmol) was added and the reaction stirred for 4 hrs or until an insoluble off-white precipitate formed. The cleavage reagent CH_3I (2-3 cc) was added and the resulting solution stirred under CO overnight. A weighed amount of dibenzyl ether was added as an internal standard, and the solution was diluted with diethyl ether, washed with 10% HCl and saturated $NaHCO_3$, dried with $MgSO_4$ and concentrated. Iron impurities were removed from the highly colored oil by means of Flash Chromatography[8] (2 cm x 10 cm Alumina; eluant 4:1 ethyl acetate: methanol). G.L.C. analysis of the concentrated eluate indicated a 67% yield of diethyl 2-methyl-2-(3-oxobutyl)propanedioate.

Table I presents yield data and structural characterizations for diethyl 2-(3-oxopropyl)-propanedioate, diethyl 2-methyl-2-(3-oxobutyl)propanedioate and triethyl 1,1,3-propanetricarboxylate. As is clear, the yields are indeed satisfactory; nonetheless, current efforts are directed at increasing yields by use of the more polar solvent 1-methyl-2-pyrrolidinone, slow addition of cyclopropane to the iron nucleophile and higher CO pressures.

Table I. Products from $Fe(CO)_4^{2-}$ ring opening of diethyl 1,1-cyclopropanedicarboxylate.

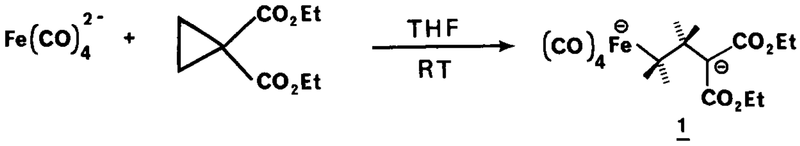
Product[a] (Yield)[d,e]	Analysis[b] (C, H)	Spectral Characterization[c]
1.  $H\overset{\overset{O}{\|}}{C}CH_2CH_2CH(CO_2CH_2CH_3)_2$ Yield: 62%	Found (55.60,7.34) Calcd. (55.55,7.46)	^1H NMR: 1.25(t,6H,7Hz,H_a), 2.13(q,2H,7Hz,H_b) 2.53(t,2H,7Hz,H_c), 3.32(t,1H,7Hz,H_d) 4.12(q,4H,7Hz,H_e), 9.67(s,1H,H_f) IR: 2983, 2819, 2719, 1750, 1733
2.  $CH_3\overset{\overset{O}{\|}}{C}CH_2CH_2C(CH_3)(CO_2CH_2CH_3)_2$ Yield: 67%	Found (58.78,8.19) Calcd. (58.99,8.25)	^1H NMR: 1.22(t,6H,7Hz,H_a), 1.32(s,3H,H_b) 2.05(m,2H,H_c), 2.07(s,3H,H_d) 2.45(m,2H,H_e), 4.12(q,4H,7Hz,H_f) IR: 2984, 1729
3.  $CH_3CH_2O\overset{\overset{O}{\|}}{C}CH_2CH_2CH(CO_2CH_2CH_3)_2$ Yield: 64%	Found (55.36,7.65) Calcd. (55.37,7.74)	^1H NMR: 1.21(t,3H,7Hz,H_a), 1.23(t,6H,7Hz,H_b) 2.15(m,2H,H_c), 2.32(m,2H,H_d) 3.38(t,1H,7Hz,H_e), 4.04(q,2H,7Hz,H_f) 4.13(q,4H,7Hz,H_g) IR: 2983, 1750(sh), 1736

[a] Cleavage Reagents: (1) HOAc, (2) CH_3I, (3) I_2/C_2H_5OH. [b] Schwarzkopf Microanalytical Lab. [c] NMR: 90 MHz, TMS internal std., neat or 50% in CCl_4. IR; 3% in CCl_4. [d] G.L.C. conditions: 6'x1/8" 10% EGA on Chromosorb W 80-100 mesh. [e] Average value of at least 2 determinations and based upon mmoles cyclopropane.

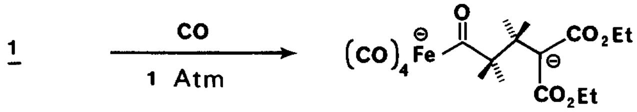
The progress of ring opening is conveniently followed by monitoring changes in the 2200-1500 CM^{-1} region of the IR spectra of reaction mixtures in THF. For example, during preparation of diethyl 2-methyl-2-(3-oxobutyl)propanedioate, IR spectra indicated the smooth disappearance of $Fe(CO)_4^{2-}$ (1878, 1776 cm^{-1}) and diethyl 1,1-cyclopropanedicarboxylate (1729 cm^{-1}). There occurred concommitant formation of an Iron Alkyl (1982, 1876, 1826 cm^{-1})[9] which, under CO, rearranged to the corresponding Iron Acyl (2007, 1916, 1888, 1586 cm^{-1}).[9] Additionally, the spectra clearly indicated the presence of a malonate carbanion (1673 cm^{-1}).[10] Addition of CH_3I to the reaction mixture produced complete loss of the Iron Acyl and malonate absorptions and appearance of the carbonyl absorption of the product (1730 cm^{-1}). Analogous spectral changes were observed during the syntheses of diethyl 2-(3-oxopropyl)propanedioate and triethyl 1,1,3-propanetricarboxylate.

Our results suggest that diethyl 1,1-cyclopropanedicarboxylate undergoes nucleophilic ring opening with $Fe(CO)_4^{2-}$ to produce an Iron Alkyl complex (eq. 1)[4,6,7] which, under an atmosphere of carbon monoxide, rapidly rearranges to the more stable Iron Acyl (eq. 2).[6,7] Scheme I presents the cleavage reactions utilized in the conversion of the Iron Acyl into the desired carbonylated products.[6,7]

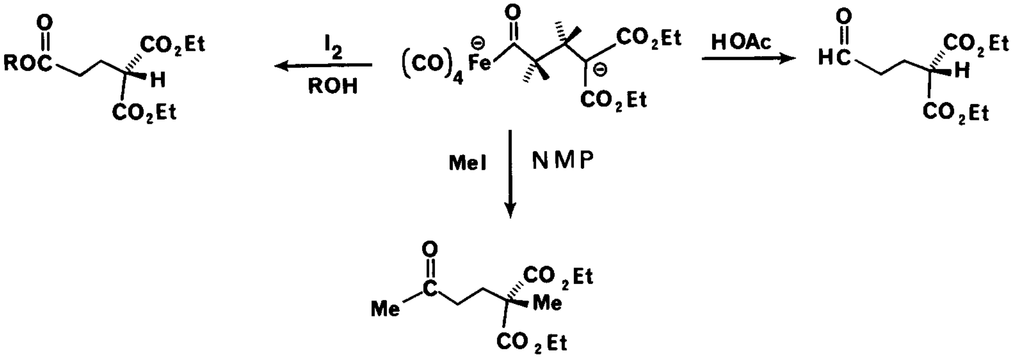
1.



2.



Scheme I



Acknowledgement.

This research was supported by a grant from Research Corporation and the Institutional Grant Fund of Franklin and Marshall College. We thank Scott Penfil and Barry Aron for their technical assistance. We thank Professor M.P. Doyle for his support and encouragement during preliminary investigations.

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(Received in USA 15 March 1983)