CHEMISTRY LETTERS, pp. 167-170, 1974. Published by the Chemical Society of Japan

# THE REACTION OF ACYLFERROCENES WITH METHYLMAGNESIUM HALIDES. THE INTERVENTION OF CARBONIUM-ION-LIKE INTERMEDIATES

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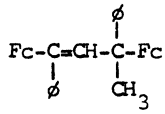
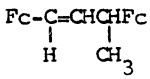
The reactions of several acylferrocenes with methylmagnesium halides are examined. Some carbinol stabilities with adsorbents are reported.

Numerous Grignard reactions have been run on acylferrocenes but only recently has detailed investigation uncovered abnormal behavior. In 1967, Horspool and Sutherland[1] found that 1,1'-diacetylferrocene(I) with $CH_3MgI$ yielded the 1,1'-diolefin(II) rather than the expected diol(III). This was in contrast to the results with $CH_3MgBr$. When we examined[2] the reaction of $CH_3MgI$ on benzoylferrocene under similar conditions we found no alcohol; instead a dimer resulted, mp 139.0-142.5°C, to which we assigned structure IV and implicated the iodo-alkoxy derivative by showing that the generation of ROMgI independent of free or starting ketones also furnished IV.



IV



V

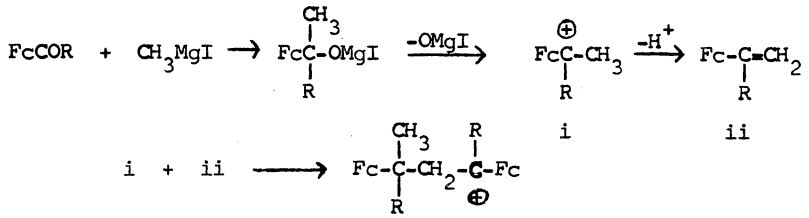
Recently[3], Horspool, analyzed the reaction of $CH_3MgI$ with acetylferrocene. They found 49% t-butylferrocene, 9% olefin, 4% a mixture of non-olefinic dimers, 27% olefinic dimers and only 3% expected alcohol. This reaction has been run several times[1,4] and the variability of results by different workers plus the complexity shown by the Horspool work suggests neglect of several experimental parameters capable of drastic effect on the product distribution. We felt it worthwhile to consider: 1. Nature of the halide 2. Solvent 3. Acidic contamination during work-up.

Results and Discussion The experiments that follow are: 1. Grignard reactions on acyl-ferrocenes and 2. carbinol stability studies. For simple Grignard reactions, we varied the halide and the solvent. Abnormal product was obtained only with iodide and the mixed system ether/benzene; in the case of acetylferrocene and $CH_3MgI$, we were unable to obtain any alcohol using ether/benzene with acetylferrocene and methylmagnesium bromide, alcohol was the predominant product whether or not benzene was added. Ferrocenecarboxaldehyde demonstrated the same behavior and, with methylmagnesium iodide appeared to give the dimer (V). With ØMgBr and

acetylferrocene, alcohol resulted with only ether or with ether/benzene solvent, in contrast to the result with the iodide[2].

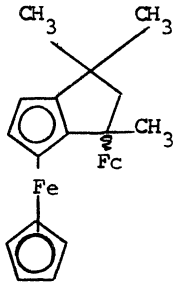
We found that the alcohol survives normal work-ups. In those cases where mild work-ups have been used neither olefin nor dimer is obtained <u>after</u> the reaction and must have arisen prior to the work-up. Our studies with adsorbent contact show that neutral short contact times should be used to avoid contaminating the carbinols. Lengthy chromatographies with acidic materials such as alumina promote isomerization.

The iodide-originated transformations most likely stem from the following type of mechanism:



When R is phenyl, proton loss to yield an olefin is the most favorable, but where R is methyl, our data are in agreement with Horspool[3,5] and indicate a homoannular closure to yield compound VI; mp 184-186°C:

VI:



Promotion of the carbonium-ion-like intermediate definitely proceeds best when OMgI is the potential leaving group and the solvent is ether/benzene. The exact reason for this is not clear, but the "cluster" nature of the Grignard reagent in benzene is well-known[6] and may facilitate ionization of the magnesium alcoholate due to higher dipole forces in the immediate area of a cluster.

<u>The Reaction of Acetylferrocene with Methylmagnesium Iodide</u>. - <u>Condition 1</u>. - Methyl iodide (9.8 ml) was dissolved in 40 ml of ether and added drop-wise to 20 ml of ether containing 2.43 g (0.1 M) of magnesium turnings to form 0.1 mole of $CH_3MgI$. Five grams of acetylferrocene dissolved in 30 ml of benzene was then added drop-wise to the $CH_3MgI$ while stirring. The mixture was hydrolyzed with water. The work-up included washing twice with 100 ml of saturated aq. $NH_4Cl$ and once with 100 ml water, then drying overnight with anhydrous $Na_2SO_4$. The product, after having been evaporated to dryness gave 4.5 g crude solid. When it was recrystallized

from 60-70°C petroleum ether, 1.3 g a final product compound VI, having a 184-186° melting point resulted. Mass spectroscopic analysis revealed P = 452(100), P-2(14), P+1(34), P+2(2). The nmr spectrum gave peaks at 0.8 $\delta$(3H), 1.2 $\delta$(3H), 1.9 $\delta$(3H), quartet centered at 2.1 $\delta$(2H) and complex multiplet 3.3-4.4 $\delta$(17H). The infrared spectrum shows bands at 3050, 2970, 2910, 2840, 1630, 1480, 1455, 1360, 1290, 1270, 1100, 1000, 805, 505, 490, 465 and 455 $cm^{-1}$.

Condition 2. - The reaction was carried out using 0.40 grams of magnesium (0.0016 moles)and 2.35 grams of methyl iodide (0.0165 moles) in 50 ml of absolute ether to form $CH_3MgI$. Next, 2.28 grams of acetylferrocene (0.0100 moles) dissolved in 50 ml of benzene was added drop-wise to the $CH_3MgI$ over a period of 30 min. After complete addition of the acetylferrocene, the mixture was stirred for a period of twenty min. The reaction product was washed twice with 100 ml portions of cold, saturated aqueous $NH_4Cl$. The benzene/ether solution containing the product was then dried over anhydrous $Na_2SO_4$. Evaporation of the solvent yielded 1.0 grams of crude red oil.

A non-polar compound was eluted from a neutral silica column with 30-60°C petroleum ether and evaporation of the solvent yielded 0.09 grams of yellowish-orange solid, mp 64-66°C. No further investigation was performed except to note a significant amount of unchanged acetylferrocene. Attempts at recrystallization of the compound with hexane resulted in decomposition.

The infrared spectrum indicated the presence of a monosubstituted ferrocene by the strong absorptions at 1125 $cm^{-1}$ and 1025 $cm^{-1}$. The presence of a strong peak at 1625 $cm^{-1}$ indicated an alkene. The nmr spectrum showed a singlet at 2.10 $\delta$(3H), a multiplet at 4.20 $\delta$(9H), a doublet at 4.85 $\delta$(1H) and a doublet at 5.12 $\delta$(1H).

The Reaction of Acetylferrocene with Methylmagnesium Bromide. - The Grignard reagent was prepared using 0.66 g magnesium (0.027 mole) and 4.50 g methyl bromide (0.029 mole) in 30 ml ether. To this solution was then added 2.50 g acetylferrocene (0.0109 mole) in 15 ml ether. The resultant solution was refluxed 2 hrs, worked-up as described above with saturated aq. $NH_4Cl$, water and anhydrous $Na_2SO_4$ to yield 1.8 g (72%) crude alcohol mp 54-57.5°C (lit[4] 56.58°C).

When the same reaction was carried out except for the substitution of a 1:1/benzene:ether solution the same results were obtained with the exception that a small amount of $\alpha$-methylvinylferrocene was found as a contaminant.

The Reaction of Ferrocenecarboxaldehyde with Methylmagnesium Iodide. - Ferrocenecarboxaldehyde (0.43 g) was allowed to react with $CH_3MgI$ in the usual manner using ether/benzene to yield 0.25 g a reddish oil whose infrared spectrum was identical to the dimer reported by Goldberg[7].

The Reaction of Acetylferrocene with Phenylmagnesium Bromide. - In a 400 ml standard taper round-bottom flask was placed a solution of 50 ml dry ether and 10.4 ml ØMgBr (2.10 M). To this solution, maintained at room temperature, was slowly added, with stirring, a dry ether solution of 0.5 grams acetylferrocene in 100 ml dry ether. The Grignard solution immediately turned milky red-orange and then to yellow. After addition was complete, the reaction was stirred at room temperature for one hour. At the end of that time saturated aqueous ammonium chloride was added and the ether solution withdrawn, washed once with water, dried over anhydrous sodium sulfate and analyzed via TLC. A qualitative TLC showed one compound whose Rf was 0.5. It proved to be the expected carbinol exclusively. The nmr spectrum gave peaks at 1.8$\delta$(3H), 2.4$\delta$(1H), 4.3$\delta$(9H) and 7.3$\delta$(5H).

Stability of Dimethylferrocenylcarbinol. - A solution of 100 mg dimethylferrocenylcarbinol, mp 59.5-61.5°C, in 20 ml ether and 20 ml benzene was shaken two times with saturated aqueous ammonium chloride after the fashion customarily employed, then washed with water and dried over anhydrous sodium sulfate overnight. It was filtered and evaporated to dryness to yield 90 mg yellow needles, mp 58-60°C. TLC analysis showed the presence of only a small amount of new material, Rf ca 0.9 and a great deal of the starting alcohol.

Stability of Methylphenylferrocenylcarbinol. - Alcohol samples were metered-out, 20 mg each in $CH_2Cl_2$ and stirred for 2 hrs with alumina, SILICAR$^R$ and silica gel respectively, then analyzed with TLC plates which were still hot (60°C); great losses of alcohol were noted in all cases. With "cured" plates that were allowed to cool, no effect was noted.

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(Received November 13, 1973)