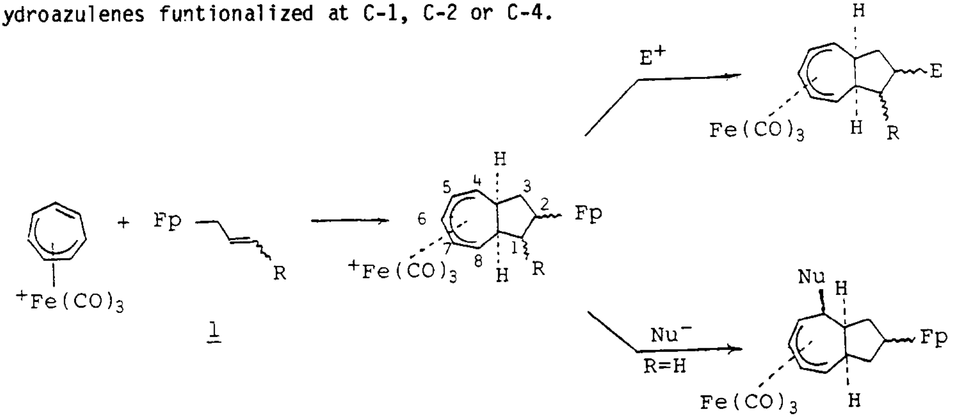
Tetrahedron Letters,Vol.25,No.20,pp 2097-2100,1984 0040-4039/84 $3.00 + .00
Printed in Great Britain

[3+2] Cyclopentane Annulation Reactions Using Organoiron Reagents. Hydroazulene Synthesis.

J. C Watkins and M. Rosenblum*
Department of Chemistry, Brandeis University
Waltham, Massachusetts 02254

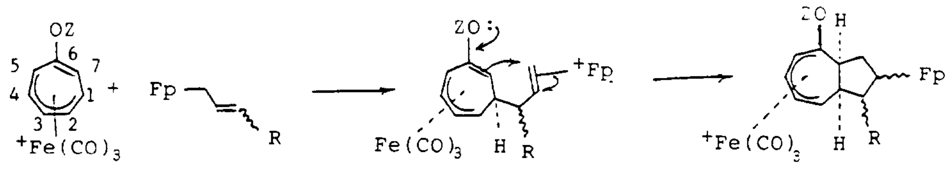
Summary: A one step synthesis of 4-ketohydroazuleneiron complexes 6,7 and 8 from troponeiron tricarbonyl is described.

We have shown that tropyliumiron tricarbonyl enters into stepwise [3+2] cycloaddition reactions with (η^1-allyl Fp complexes 1 [$\mathrm{Fp}=\eta^5\text{-}C_5H_5Fe(CO)_2$] and their propargyl and allenyl congeners, and that these products may be further elaborated through reaction with electrophiles or nucleophiles.[1] Such sequences provide simple and efficient entry to hydroazulenes funtionalized at C-1, C-2 or C-4.



1

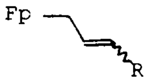
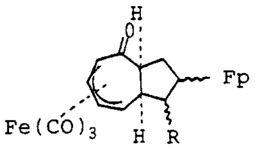
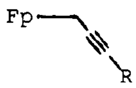
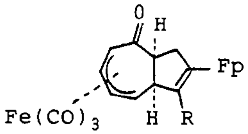
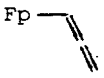
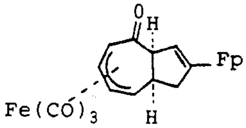
In order to further examine the synthetic potential of this sequence, especially for the construction of guaianolide sequiterpenes, we have begun a study of functionalized tropyliumiron complexes as partners in these cycloaddition reactions. We now find that the readily available troponeiron tricarbonyl[2] may be suitably activated toward cycloaddition by reaction with either trimethylsilyl triflate or n-butylboryl triflate, at -78°, in methylene chloride solution. Treatment of the resulting trimethylsilyloxy- or di-n-butylboryloxytropylium salts 2 with a number of Fp synthons (1,4,5), followed by hydrolysis, has been found to yield 4-ketohydroazulene complexes (6,7,8) as the sole product of cycloaddition. These reactions may be depicted as proceeding through initial attack of the organometallic nucleophile at C-1, the least hindered terminal carbon atom of the pentadienyl ligand in a 6-substituted tropyliumiron tricarbonyl cation 2, followed by closure of the intermediate complex 3 through the uncomplexed enol double bond. This sequence is illustrated below for the reaction of Fp(η^1-allyl) complexes with the tropylium cation. Cycloaddition products formed with a number of Fp synthons are summarized in Table 1.[3]



2 1 3

Z = $SiMe_3$, BBu_2

Table I Cycloaddition Products

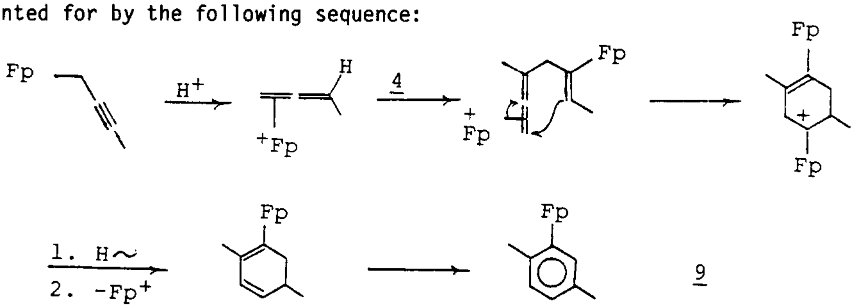
Nucleophile	R	Activator	Product	R	% Yield
 1	H	a	 6	H	58
	H	b		H	60
	Me	b		Me	62
 4	Me	a	 7	Me	23
	Me	b		Me	92
	$SiMe_3$	b		H	62[c]
 5	a		 8		26
	b				55

a. TMS OTf b. Bu_2BOTf c. the TMS group is lost during the reaction

Structural assignments of these as 4-ketohydroazulene complexes follow from the presence of 4-proton NMR resonances characteristic of the dieneiron tricarbonyl group (δ 5.2-5.8 and 2.4-2.6) and of low frequency carbonyl absorption in the IR (ν 1620 cm^{-1}) in the spectra of all cycloaddition products. Shift reagent experiments with $Eu(fod)_3$ on 7 confirm the placement of the Me group at C-1 in this substance. Finally, the stereochemical relationship of the hydrogens at C-3a, 8a with respect to the Fe(CO)$_3$ group, in all of the cycloadducts, follows from well precedented trans addition of nucleophiles to pentadienyliron cations.[1,4]

A typical experimental procedure, illustrative of the method is as follows. A solution of troponeiron tricarbonyl (0.42 g., 1.7 mmol) in freshly distilled methylene chloride was placed under argon and cooled to -78°. An equivalent of di-n-butylboryl triflate was added to this via syringe. After 3 hours at -78°, an ir spectrum of the solution showed complete disappearance of absorption at 1631 cm^{-1} characteristic of the starting material. To this solution was added via cannula, 2.2 g (9.6 mmol) of 1-Fp-2-butyne[5] 4 (R=Me) dissolved in 10 ml of methylene chloride and cooled to -78°. The solution was stirred for 2 hours at -78°, then warmed to room temperature and was finally refluxed for 2 hours. The reaction was quenched by adding absolute ethanol and solid potassium carbonate and stirring at room temperature for 12 hours. The solution was then filtered through celite, solvent was removed and the product was chromatographed on silica gel (EtOAc-Skelly, 1:1). The trailing yellow bands were collected and chromatographed again on alumina (basic, activity IV) by the dry column technique (11x2 cm nylon, EtOAc-Skelly 1:2) to give 0.74 g of 7 (R=Me) as an amber oil.

The use of excess 4 (R=Me) is advantageous since part of it is converted, in the presence of a trace of acid to the p-xylene complex 9, which is isolated from the leading yellow band of the silica gel column as a dark yellow oil (252 mg): IR (CH$_2$Cl$_2$) 2970, 2940, 2010, 1960, 1040 cm^{-1}, NMR (CDCl$_3$) δ 7.45 (s, 1H), 6.95 (d, 1H, J = 9 Hz), 6.70 (d, 1H, J = 9 Hz) 4.84 (s, 5H), 2.40 (s, 3H), 2.20 (s, 3H). The formation of 9 may be accounted for by the following sequence:

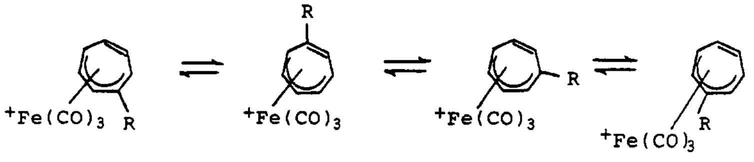


9

The use of 3-substituted Fp(allyl) complexes thus provides a simple route to derivatives of the parent complex system with a substituent at C-1 and a carbonyl function at C-4 of the hydroazulene skeleton, while the use of the more highly unsaturated propargyl or allenyl Fp complexes allows for regiocontrol in the introduction of unsaturation in the five membered ring as well.

The formation of a single regioisomeric cycloadduct in all of these reactions is remarkable in view of the spectral analysis of alkyl substituted tropyliumiron tricarbonyls, which show these to be mixtures of two or more structural isomers in rapid equilibrium.[6]

The predominant isomers for R=Me, Ph, c-C_3H_5 and i-C_3H_7 were found to be the C-2, 4 and C-6 substituted isomers 10 and 11.



10 11

The present results may be accounted for either in terms of the presence of only the latter cation when R=$OSiMe_3$ or $OBBu_2$ or of the preferential reaction of this isomer among the several in equilibrium, but the available evidence does not allow us to distinguish between these possibilities.

Finally, removal of the Fp group in 7 (R=Me) is readily accomplished, in 95% yield, by exposure to 1 M sulfuric acid (THF, 25°, 1 h). The replacement of Fp, in an analog of 6 (CH_2 in place of CO, R=Me) by COOMe or Br has been reported,[1] as has the release of the hydroazulene ligand from the $Fe(CO)_3$ group with Ce(IV) salts.[1] This latter reaction is, of course, well precedented in the chemistry of dieneiron tricarbonyl complexes.[4]

Further use of these reactions in sesquiterpene synthesis is being pursued.

Acknowledgment. Support for this work was derived from a grant (CHE-8117510) from the National Science Foundation, which is gratefully acknowledged.

References

1. N. Genco, D. Morten, S. Raghu, M. Rosenblum, J. Am. Chem. Soc., 98, 848 (1976).
2. D. F. Hunt, G. C. Farrant, G. T. Rodeheaver, J. Organometal. Chem., 38, 349 (1972).
3. All new compounds were characterized by IR and NMR spectra and gave satisfactory elemental analysis.
4. A. J. Pearson, Acc. Chem. Res., 13, 463 (1980).
5. M. R. Churchill, J. Wormald, D. A. Ross, J. E. Thomasson, A. Wojcicki, J. Am. Chem. Soc., 92, 1795 (1970).
6. C. P. Lewis, W. Kitching, A. Eisenstadt, M. Brookhart, J. Am. Chem. Soc., 101, 4896 (1979).

(Received in USA 10 February 1984)