MOBILITY OF HYDROGEN ATOMS IN MONO- H- POLYFLUOROALKANES AND RELATED COMPOUNDS

COMMUNICATION 2. 2H-HEXAFLUORO-2-(TRIFLUOROMETHYL)PROPANE

IN THE MICHAEL REACTION*

I. L. Knunyants, S. T. Kocharyan, and E. M. Rokhlin

In view of the known proton mobility of hydrogen atoms in mono-H-polyfluoroalkanes [2] it could be expected that these compounds would be able to undergo the reactions characteristic for compounds containing an active methylidyne group. However, up to now there has been no significant information in the literature on the application of the mobility of hydrogen atoms in mono-H-polyfluoroalkanes in synthesis. We can refer only to the synthesis of the secondary alcohols (I) from propionaldehyde and 1H- and 2H-heptafuoroalkanes (II) via the corresponding organolithium compounds (III) [2]:

\[
\begin{align*}
\text{R}_1 + \text{H} + \text{CH}_2\text{Li} & \rightarrow \text{R}_1 - \text{Li} \rightarrow \text{CH}_2\text{H}_3 \\
\text{R}_1 & = \text{CF}_2\text{CF}_2\text{CF}_2 \text{ or } (\text{CF}_3)_2\text{CF}
\end{align*}
\]

However, the alcohols (I) were obtained in low yields and in the form of difficultly separable mixtures with other reaction products.

The accumulation of perfluoroalkyl groups raises the acidity of mono-H-polyfluoroalkanes, but also facilitates the elimination of fluorine atoms in the form of ions under the action of bases. Thus, 2H-hexafluoro-2-(trifluoromethyl)propane (IV) (pK \(\approx 11\)) is very readily split under the action of alkalies [2]:

\[
\begin{align*}
P & \rightarrow \text{CF}_2\text{CF}_2\text{CF}_2 \\
P & \rightarrow \text{CF}_2\text{CF}_2
\end{align*}
\]

To bring compounds of the type of 2H-hexafluoro-2-(trifluoromethyl)propane into reaction at the active methylidyne group (Michael reaction, aldol condensation, C-acylation, etc.) it is necessary to choose a basic catalyst such that it will polarize the C–H bond sufficiently without bringing about the mineralization of fluorine atoms.

We have shown previously that under the action of triethylamine 2H-hexafluoro-2-(trifluoromethyl)propane is dehydrofluorinated reversibly and that the equilibrium is very much on the side of the formation of the original reactants [1]. It could be hoped, therefore, that triethylamine would be found to be a suitable catalyst for the condensation reactions of 2H-hexafluoro-2-(trifluoromethyl)propane. However, an attempt to use triethylamine as a catalyst in the C-acylation of 2H-hexafluoro-2-(trifluoromethyl)propane was not successful: in the reaction with benzoyl chloride, instead of the expected ketone (V), perfluoroisobutene (VI) was formed as a result of the displacement of the equilibrium to the right [1]

\[
\begin{align*}
(\text{CF}_3)_2\text{CH} + (\text{C}_6\text{H}_5)_3\text{N} & \rightarrow (\text{CF}_3)_2\text{C} = \text{CF}_2 + (\text{C}_6\text{H}_5)_3\text{N} \cdot \text{HF} \\
+ & \text{C}_6\text{H}_5\text{COCl} \\
\text{CF}_3\text{COF} + (\text{C}_6\text{H}_5)_3\text{N} \cdot \text{HCl}
\end{align*}
\]

* For communication 1 see [1].
However, in the present work we have shown that triethylamine can be used successfully as a catalyst in the Michael reaction in the case of 2H-hexafluoro-2-(trifluoromethyl)propane and related compounds. It was found that in presence of triethylamine 2H-hexafluoro-2-(trifluoromethyl)propane adds at the double bond of acrylic systems — acrylonitrile, methyl acrylate, and acrolein. In this way we obtained 5,5,5-trifluoro-4,4-bistrifluoromethylvaleronitrile (VIIa), methyl 5,5,5-trifluoro-4,4-bistrifluoromethylvalerate (VIIb), and 5,5,5-trifluoro-4,4-bistrifluoromethylvaleraldehyde (VIIc):

\[(\text{CF}_3)_2 \text{CH} + \text{CH}_2 = \text{CH} \rightarrow \text{CF}_3 \text{C}_2 \text{H}_2 \text{CHX} \quad (\text{VII})\]

(VII): a) \(X = \text{CN}\); b) \(X = \text{COOCH}_3\); c) \(X = \text{CHO}\)

3,3,3-Trifluoro-2-(trifluoromethyl)propionic and (trifluoromethyl)malonic esters (VIII) and (IX) react analogously with greater ease, which confirms that alkoxycarbonyl groups have a stronger activating action than perfluoroalkyl groups. The cyanoethylolation of the esters (VIII) and (IX) leads to the corresponding 2-cyanoethyl derivatives (X) and (XI):

\[(\text{CF}_3)_2 \text{CHCOOCH}_3 + \text{CH}_2 = \text{CHCN} \rightarrow \text{CF}_3 \text{C}_2 \text{H}_2 \text{CHCN} \rightarrow \text{CF}_3 \text{C}_2 \text{H}_2 \text{COOC}_2 \text{H}_5 \quad (\text{VIIa}) \]

By the hydrolysis of 5,5,5-trifluoro-4,4-bistrifluoromethylvaleronitrile (VIIa) we obtained the corresponding amide (VIIId) and acid (VIIe). Ethyl 5,5,5-trifluoro-4,4-bistrifluoromethylvalerate (VIIf) was obtained by heating the nitrile with concentrated sulfuric acid in presence of diethyl ether:

\[(\text{CF}_3)_2 \text{CHCOOCH}_3 \rightarrow \text{CF}_3 \text{C}_2 \text{H}_2 \text{CONH}_2 \quad (\text{VIIId}) \]

Reduction of the aldehyde (VIIc) or ester (VIII) led to 5,5,5-trifluoro-4,4-bistrifluoromethyl-1-pentanol (XII), and reduction of the nitrile (VIIa) led to 5,5,5-trifluoro-4,4-bistrifluoromethylpentylamine (XIII), which was characterized in the form of the corresponding substituted phenylurea (XIV):

Thus, in its application to 2H-hexafluoro-2-(trifluoromethyl)propane the Michael reaction opens up fairly wide possibilities in the synthesis of various compounds containing the perfluoro-t-butyl group.

As regards the mechanism of this reaction, it may be supposed that it is effected with intermediate formation of the carbanion (XV), which reacts at the activated double bond:

\[(\text{CF}_3)_2 \text{CH} \quad (IV) \rightarrow (\text{CF}_3)_2 \text{CH} = \text{CF}_3 \quad (V) \]

\[(\text{CF}_3)_2 \text{CH} \quad (XV) \rightarrow (\text{CF}_3)_2 \text{CH} = \text{CF}_3 \quad (V) \]

\[(\text{CF}_3)_2 \text{CH} \quad (XV) \rightarrow (\text{CF}_3)_2 \text{CH} = \text{CF}_3 \quad (V) \]

Thus, in its application to 2H-hexafluoro-2-(trifluoromethyl)propane the Michael reaction opens up fairly wide possibilities in the synthesis of various compounds containing the perfluoro-t-butyl group.