

The oil, covered with dry methanol, was allowed to remain in a refrigerator for one week. The mixture of crystals and oil was filtered through a fritted-glass funnel surrounded by ice. After thorough trituration with cold methanol, the crystals melted at 49–51°.

Anal. Calcd. for $C_{14}H_{13}O_2SBr$: S, 9.86; Br, 24.57. Found: S, 9.63; Br, 24.53.

When either the oily product or the crystalline material was aminated with diethylamine, the 4-diethylaminomethyl dioxolane obtained boiled at 135–139° (0.01 mm.).

Anal. Calcd. for $C_{15}H_{25}O_2NS$: N, 4.41; S, 10.10. Found: N, 4.24; S, 10.24.

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RECEIVED OCTOBER 11, 1951

[CONTRIBUTION FROM THE PURDUE UNIVERSITY DEPARTMENT OF CHEMISTRY AND THE PURDUE RESEARCH FOUNDATION]

The Reducing Action of Grignard Reagents on Fluorinated Carbonyl Compounds^{1,2}

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The reaction of Grignard reagents with trifluoroacetaldehyde, pentafluoropropionaldehyde, heptafluorobutyraldehyde, the esters of trifluoroacetic, pentafluoropropionic, and heptafluorobutyric acids, 1,1,1-trifluoroacetone, 3,3,4,4,4-pentafluoro-2-butanone and 3,3,4,4,5,5,5-heptafluoro-2-pentanone were studied in an effort to delineate the extent of the reduction observed. In all Grignard reagents containing β -hydrogens reduction was obtained, which may be attributed to the large inductive effect of the fluorinated alkyl group attached to the carbonyl grouping in these materials.

In a previous paper,³ mention was made of the reduction of pentafluoropropionaldehyde and 3,3,4,4,4-pentafluoro-2-butanone by ethyl and isopropyl Grignard reagents. In order to investigate this reaction further, the action of six Grignard reagents on both trifluoroacetaldehyde and pentafluoropropionaldehyde was compared to determine if the amount of fluorine present affects the degree of reduction and to evaluate the effect of the structure of the alkyl group of the Grignard reagent on the product obtained. In addition, the study was extended to the action of ethylmagnesium iodide on esters of trifluoroacetic, pentafluoropropionic and heptafluorobutyric acids as well as 1,1,1-trifluoroacetone, 3,3,4,4,4-pentafluoro-2-butanone, 3,3,4,4,5,5,5-heptafluoro-2-pentanone and heptafluorobutyraldehyde. The comparative amounts of addition and reduction products are summarized in Tables I and II.

Generally, reduction of carbonyl compounds by Grignard reagents has been observed in instances in which the addition reaction may be hindered sterically.⁴ Hence the reduction previously observed³ with fluorinated derivatives of propionaldehyde and 2-butanone was unexpected because of the absence of large groups and hence any significant steric factor. The results of this investigation indicate that an inductive effect, due to the close proximity of a highly electronegative fluorinated group to the carbonyl group, is affecting the course of the Grignard reaction to cause an abnormal amount of reduction. Recent work by Campbell and co-workers⁵ shows that reduction also occurs in the reaction of esters of trifluoroacetic acid with Grignard reagents.

The pronounced effect of fluorine substitution on the nature of the reaction of a Grignard reagent

(1) This paper represents part of a thesis submitted by J. F. Higgins to the Graduate School, Purdue University, in partial fulfillment of the requirements of the degree of Doctor of Philosophy. This work was supported by the Westinghouse Electric Corporation.

(2) Presented before the Organic Section, XIIth International Congress of Pure and Applied Chemistry, New York, N. Y., September, 1951.

(3) E. T. McBee, J. F. Higgins and O. R. Pierce, in press.

(4) J. B. Conant and A. H. Blatt, *ibid.*, **51**, 1227 (1929).

(5) K. N. Campbell, J. O. Knobloch and B. K. Campbell, *ibid.*, **72**, 4380 (1950).

TABLE I

Grignard reagent	CF ₃ CF ₂ CHO		CF ₂ CHO	
	Redn., %	Addn., %	Redn., %	Addn., %
Methyl	0	87.0	0	67.0 ^a
Ethyl	55.5	33.6	20.0	60.0
Isopropyl	90.0	0	87.0	0
<i>t</i> -Butyl	76.2	14.3	84.0	7.0
Phenyl	0	86.0	0	88.0
Benzyl	0	83.0	0	81.0

^a This reaction was conducted by Dr. J. A. Barone.

TABLE II

Compound	REACTIONS WITH ETHYL GRIGNARD	
	Redn., %	Addn., %
CF ₃ CO ₂ CH ₃ ^a	35.0	56.0
C ₂ F ₅ CO ₂ CH ₃	66.0	29.0
C ₃ F ₇ CO ₂ CH ₃ ^b	68.6	12.5
CF ₃ COCH ₃	13.9	78.9
C ₂ F ₅ COCH ₃	44.5	41.6
C ₃ F ₇ COCH ₃	61.6	18.0
C ₃ F ₇ CHO	61.0	19.0

^a Campbell, ref. 5, synthesized the addition and reduction products obtained in this reaction from ethyl Grignard and ethyl trifluoroacetate and butyl trifluoroacetate, respectively.

^b Private communication.

with a carbonyl group is particularly apparent in the reaction of trifluoroacetaldehyde with isopropylmagnesium iodide. Although the principal, if not exclusive, reaction of acetaldehyde with a Grignard reagent is addition, trifluoroacetaldehyde undergoes 87% reduction to trifluoroethanol and none of the expected adduct was isolated. Since a fluorine atom is only a little larger than a hydrogen atom and hence a trifluoromethyl group is about the same size as methyl, this reducing action cannot be readily attributed to steric factors.

The experimental results indicate (Tables I and II) that as the length of the perfluorinated chain increases, the amount of reduction increases with a corresponding decrease in addition. This was found to be most significant when using ethyl Grignard reagent with trifluoroacetaldehyde and pentafluoropropionaldehyde. In the case of trifluoroacetaldehyde, the yield of reduction and addition products were 20 and 60%, respectively,

TABLE III
 NEW COMPOUNDS

Compound	B.p.	n_D^{20}	d_4^{20}	Analyses, %			
				Carbon		Hydrogen	
				Calcd.	Found	Calcd.	Found
$\text{CF}_3\text{CHOHC}_6\text{H}_5$	64-65 ^a	1.4610	1.293	54.54	54.55	3.97	4.02
$\text{CF}_3\text{CF}_2\text{COH}(\text{C}_2\text{H}_5)_2$	127	1.3590	1.259	40.78	40.78	5.34	5.39
$\text{CF}_3\text{CF}_2\text{CHOHC}_6\text{H}_5$	52 ^b	1.4340	1.366	47.79	48.00	3.10	3.12
$\text{CF}_3\text{CF}_2\text{CF}_2\text{C}(\text{OH})(\text{CH}_3)\text{C}_2\text{H}_5$	125	1.3395	1.396	34.71	34.85	3.72	3.75
$\text{CF}_3\text{CHOHCH}_2\text{C}_6\text{H}_5$	74-76 ^c	1.4662	1.234	56.84	56.80	4.74	4.64
$\text{CF}_3\text{C}(\text{OH})(\text{CH}_3)\text{C}_2\text{H}_5$	98.3	1.3540	1.161	42.25	42.20	6.34	6.33
$\text{CF}_3\text{CF}_2\text{CHOHCH}_2\text{C}_6\text{H}_5$	79 ^c	1.4430	1.330	50.00	50.10	3.75	3.85
$\text{CF}_3\text{CHOHC}(\text{CH}_3)_3$	110.5	1.3670	1.118	40.78	40.71	5.34	5.45
$\text{CF}_3\text{CF}_2\text{CHOHC}(\text{CH}_3)_3$	120	1.3578	1.105	46.15	45.95	7.05	6.95

^a 5 mm. ^b 3 mm. ^c 5 mm.

while with pentafluoropropionaldehyde they were 55.5 and 33.6%. This increase in the relative amount of reduction obtained, as the amount of fluorine in the carbonyl compound is increased, may be attributed to the increasing positive charge on the carbonyl carbon atom, resulting from the increased inductive effect.

A possible explanation for the reduction reaction can be found in the work of Whitmore⁶ who postulated a cyclic process involving formation of a six-membered ring followed by a shift of a hydride ion from the Grignard reagent. In the case of fluorinated aldehydes, ketones and esters, the inductive effect of the fluorine atoms should provide an increased driving force for the hydride ion shift and thus accelerate the reduction process relative to the competitive addition reaction. In support of this postulate, it was found that the reaction of ethyl Grignard with pentafluoropropionaldehyde, which usually gives about 33% addition and 55% reduction products, gave 58% addition and 36.4% reduction when the aldehyde was added to a solution of magnesium bromide before addition of the Grignard reagent. This parallels the results of Swain⁷ and is cited as additional evidence for a cyclic reduction process.

The increase in the relative amount of reduction obtained as the Grignard reagent is varied from ethyl to isopropyl can be explained by the increasing number of β -hydrogen atoms in the alkyl group of the Grignard reagent. The addition of tertiary butyl Grignard to the aldehydes in low yields, as contrasted with no addition with isopropyl Grignard, might result from a lesser tendency for the tertiary butyl Grignard reagent to coordinate with the carbonyl group of the aldehyde because of the

increased electron density on the magnesium which results from the electron donating property of the methyl groups. Thus, the rate of reduction would not overshadow the rate of addition as completely. This is similar to the behavior of *t*-butyl Grignard with benzophenone in which case exclusive addition is obtained as contrasted to isobutyl Grignard which reduces benzophenone exclusively.⁸ No reduction was noted with methyl, benzyl or phenyl Grignard reagents, which was expected since they lack a β -hydrogen atom.⁹

Experimental

The Grignard reagents used were prepared by standard methods from the alkyl iodides in the case of methyl and ethyl, the alkyl bromides for isopropyl and phenyl and the alkyl chlorides for *t*-butyl and benzyl. After preparation, they were filtered through glass wool, using nitrogen pressure, into a dropping funnel and added to the reaction flask. The latter was equipped with a Tru-boretype stirrer and a condenser attached to a Dry Ice cooled trap. A gas inlet tube reaching just over the surface of the liquid was used for introducing the aldehydes and 1,1,1-trifluoroacetone. A dropping funnel was used for introducing the other ketones and esters. The reaction flask was stirred and cooled in an ice-bath while the carbonyl compound was introduced. After all the carbonyl compound was added the reaction mixture was hydrolyzed in the flask with 10% sulfuric acid, the ether layer separated, and dried with Drierite. The ether was removed by distillation and the remaining liquid rectified through a Todd column. Two- to three-tenths mole of carbonyl compound was used with approximately twice the theoretical quantity of Grignard reagent. The experiment using magnesium bromide was conducted as described by Swain,⁷ but hydrolysis was effected with 10% sulfuric acid. The reduction products obtained with esters were secondary alcohols presumably formed by reduction of the intermediate ketone.⁶ Physical constants and analyses are listed in Table III.

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RECEIVED SEPTEMBER 4, 1951

(6) F. C. Whitmore, paper presented before the Atlantic City Meeting of the American Chemical Society, April, 1943.

(7) C. G. Swain and H. B. Boyles, *THIS JOURNAL*, **73**, 870 (1951).

(8) M. S. Kharasch and S. Weinhouse, *J. Org. Chem.*, **1**, (1936).

(9) F. C. Whitmore and R. S. George, *THIS JOURNAL*, **64**, 1239 (1942).