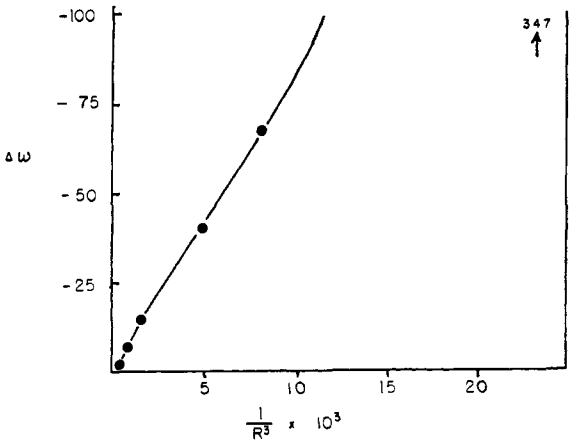

Figure 2. Plot of measured paramagnetic shifts (Table I) *vs.* the cubed reciprocal distance of the proton from the coordination site. Distances were measured from a molecular model of scale 1 Å/in.

to the tools applied in conformation studies of steroids and other similar compounds. Undoubtedly, other rare earth compounds will be of similar use[12] and application will not be confined to steroids. The ability of $Eu(DPM)_3 \cdot 2py$ to produce relatively large, concentration-dependent shifts without serious broadening suggests that the compound may have value as a shift reagent. There are a number of investigations in progress pertinent to the application of the reagent. These include interpretation of spectra obtained when more than one coordination site is available and the examination of cases for which the angular variables (eq 1) are more significant.

Acknowledgments. The author is indebted to Dr. D. M. Gruen and the Argonne National Laboratory for a sample of Eu_2O_3. Consultations with Dr. F. Patil of Southern Illinois University concerning cholesterol were extremely helpful. Mr. W. A. Boyd took the pmr spectra. The Varian HA100 nmr spectrometer was purchased with the aid of a grant from the National Science Foundation.

(12) A referee pointed out that Co^{2+}-induced contact shifts have been used in pmr studies of proteins; see C. C. McDonald and W. D. Phillips, *Biochem. Biophys. Res. Commun.*, **35**, 43 (1969).

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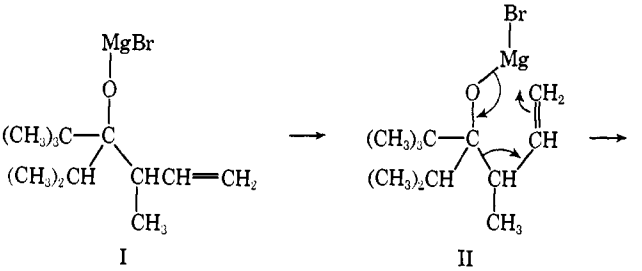
Received June 27, 1969

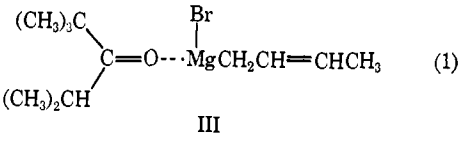
The Reaction of Crotylmagnesium Bromide with Hindered Ketones. The First Examples of a Reversible Grignard Reaction

Sir:

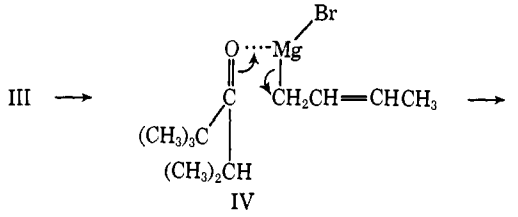
Although reversible condensations, involving the reaction of organoalkali reagents with carbonyl-containing compounds (*e.g.*, aldol,[1] Claisen,[2] and Michael[3] reactions), have been known for quite some time, it is interesting that there has never been a report of a reversible Grignard reaction. This may be due, in large part, to the greater degree of covalent character in the magnesium–oxygen bond of the Grignard product when compared to the alkali metal–oxygen bonds.[1,4]

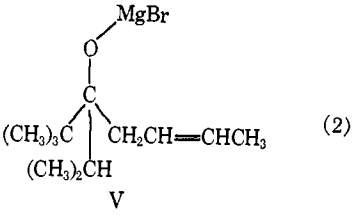
We have found that the reaction of crotylmagnesium bromide with *t*-butyl isopropyl ketone in THF produces a high yield of α-methylallyl addition product (I) initially which then diminishes with time (Table I). Commensurate with this decrease is an increase in the yield of crotyl products (V) and *t*-butyl isopropyl ketone.



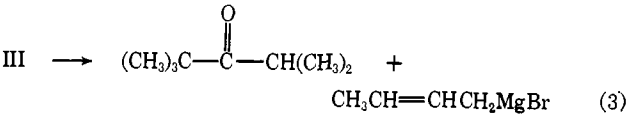


(1)





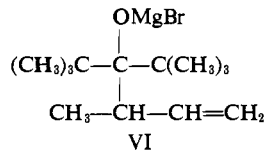
(2)



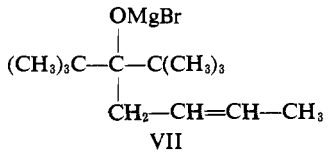
(3)

The data shown in Table I strongly suggest that the α-methylallyl-*t*-butylisopropylcarbinoxymagnesium bromide (I) is reversing with time (eq 1) into a *t*-butyl isopropyl ketone–crotylmagnesium bromide complex (III), which then collapses, possibly through a four-membered transition state (IV), to form the more thermodynamically stable crotyl products (V). The latter could also conceivably form by a complete dissociation of complex III into starting ketone and crotyl Grignard (eq 3) followed by a recombination of the two species. Employing the principle of microscopic reversibility, it is not unreasonable to assume that this reversibility (eq 1) proceeds through the same cyclic six-membered transition state (II) that was proposed to account for the formation of α-methylallyl products from the reaction of crotylmagnesium bromide with carbonyl groups.[5]

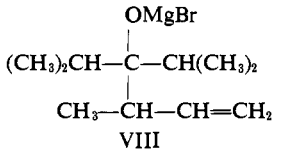
(1) C. R. Hauser and W. H. Puterbaugh, *J. Amer. Chem. Soc.*, **75**, 4756 (1953).
(2) C. R. Hauser and B. E. Hudson, Jr., *Org. Reactions*, **1**, 266 (1942).
(3) E. D. Bergmann, D. Ginsburg, and R. Pappo, *ibid.*, **10**, 179 (1959).
(4) D. J. Cram, *et al.*, *J. Amer. Chem. Soc.*, **81**, 5760, 5767, 5774 (1959).
(5) W. G. Young and J. D. Roberts, *ibid.*, **68**, 1472 (1946).



VI



VII



VIII

The driving force for this reversibility seems to be the release of steric compression about the carbinol carbon, since we have also found that α-methylallyldi-*t*-butylcarbinoxymagnesium bromide (VI) reverses[6] much more rapidly than I and that α-methylallyldiisopropylcarbinoxymagnesium bromide (VIII) remains unchanged under identical reaction conditions. When these reactions are carried out in diethyl ether, the rates of reversal are much slower than in THF. This difference can probably be attributed to the greater basicity of THF.[9]

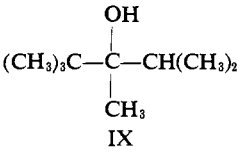
Table I. Reaction[a,b] of Crotylmagnesium Bromide with *t*-Butyl Isopropyl Ketone in THF

Time	*t*-Butyl isopropyl ketone,[c] %	Carbinol products, % α-Methylallyl	*trans*-Crotyl	*cis*-Crotyl
5 min	6.4	78.6	3.3	6.7
6 hr	8.0	51.6	11.1	22.3
24 hr	7.8	19.6	19.0	40.7
48 hr	7.8	8.5	23.7	56.2
72 hr	8.7	2.5	23.4	56.1
96 hr	9.6	1.8	24.0	59.7
192 hr	10.3	.8	22.7	61.7

[a] It should be noted that the values listed in both Tables I and II are actual *yields* of products since internal standards were employed in the vpc analysis. Accordingly, it becomes apparent that the material balance in every case was quite high. [b] The initial concentration of the ketone was 0.3 *M* and Grignard reagent was present in 10% excess. [c] Several explanations occur to us for this unexpected formation of ketone in the presence of presumed excess Grignard reagent. Dr. E. C. Ashby (private communication) has kindly suggested that the purity of the magnesium may play an important role here. Further work will be necessary to assess the importance of such variables.

The conversion of I to its crotyl isomers (V), presumably *via* a cyclic transition state (II), was further substantiated by treating an isomeric mixture of butenyl-*t*-butylisopropylcarbinols (of which 87.0% was the α-methylallyl isomer, 4.5% *trans*-crotyl isomer, and 8.5% *cis*-crotyl isomer), with *1 equiv* of methylmagnesium bromide, in THF (Table II). These results clearly show a smooth increase in the yields of the *cis*- and *trans*-crotyl isomers and *t*-butyl isopropyl ketone accompanying the decrease of the α-methylallyl isomer. Again, the rate of disappearance of the α-methylallyl isomer was found to be faster in THF than diethyl ether.

It is interesting to note that treatment of this isomeric mixture of alcohols with *3 equiv* of methylmagnesium bromide in THF or diethyl ether produced less than a 5% yield of *t*-butylisopropylmethylcarbinol (IX).



IX

Greater than 95% of the α-methylallyl isomer that disappeared was converted to the *cis*- and *trans*-crotyl isomers, even in the presence of this large excess of methylmagnesium bromide. This suggests that the collapse of the ketone–Grignard complex (III) to form crotyl products (eq 2) may possibly occur at a much faster rate than dissociation (eq 3).

Table II. Reaction[a,b] of Methylmagnesium Bromide with an Isomeric Mixture of Butenyl-*t*-butylisopropylcarbinols in THF

Time	*t*-Butyl isopropyl ketone,[c] %	Carbinol products, % α-Methylallyl	*trans*-Crotyl	*cis*-Crotyl
5 min	3.1	81.0	4.9	7.7
6 hr	10.1	63.0	10.0	18.5
24 hr	10.8	33.7	20.0	41.7
48 hr	12.4	13.5	23.3	49.9
72 hr	10.8	6.7	26.2	57.9
96 hr	13.1	3.0	25.5	57.3

[a] See footnote *a* in Table I. [b] The initial concentration of the carbinols was 0.3 *M* and the ratio of Grignard reagent to carbinols was 1:1. [c] As is indicated in Table I (footnote *c*), the origin of this ketone is presently under investigation.

Acknowledgment. This research was supported by the U. S. Army Research Office (Durham) to whom the authors are deeply indebted.

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(6) Earlier work[7,8] has shown that crotyl products form exclusively from the reaction of crotylmagnesium bromide with di-*t*-butyl ketone when the reaction is carried out at room temperature overnight. However, we now find that VI can be detected at *short* reaction times (*e.g.*, 5 min) in both diethyl ether and THF but reverses completely to crotyl products (VII) within 6 hr. This is a clear-cut example of a rate *vs.* an equilibrium process.

(7) K. W. Wilson, J. D. Roberts, and W. G. Young, *J. Amer. Chem. Soc.*, **72**, 218 (1950).

(8) R. A. Benkeser, *et al.*, *ibid.*, **91**, 132 (1969).

(9) Since THF is a stronger Lewis base than diethyl ether, it could be expected to complex more strongly with the magnesium atom of I, thereby causing the magnesium–oxygen bond to be more ionic in THF.

Net Inversion in the Reduction of Optically Active Cyclopropyl Bromides by Triphenyltin Hydride

Sir:

There has been much interest recently[1] in the generation and trapping of cyclopropyl radicals before configurational equilibration can occur. Evidence has been presented[2] that the reduction of alkyl halides by triphenyltin hydride proceeds through a free-radical intermediate. We have carried out the reductions of two optically active cyclopropyl bromides in a large excess of neat triphenyltin hydride and report evidence that confirms the trapping of cyclopropyl radicals before complete configurational equilibration has occurred

(1) H. M. Walborsky, C. Chen, and J. L. Webb, *Tetrahedron Letters*, 3551 (1964); T. Ando, F. Namigata, H. Yamanaka, and W. Funasaka, *J. Am. Chem. Soc.*, **89**, 5719 (1967); J. Jacobus and D. Pensak, *Chem. Commun.*, 400 (1969); M. J. S. Dewar and J. M. Harris, *J. Am. Chem. Soc.*, **91**, 3652 (1969).

(2) H. G. Kuivila, *Accounts Chem. Res.*, **1**, 299 (1968); H. G. Kuivila, L. W. Menapace, and C. R. Warner, *J. Am. Chem. Soc.*, **84**, 3584 (1962); L. W. Menapace and H. G. Kuivila, *ibid.*, **86**, 3047 (1964).