Journal of Organometallic Chemistry
Elsevier Sequoia S.A., Lausanne
Printed in The Netherlands

Preliminary communication

Promotion by hydroxyl functions of additions of Grignard reagents to alkynes

HERMAN G. RICHEY, Jr., and FREDERICK W. VON REIN
Department of Chemistry, The Pennsylvania State University, University Park, Pennsylvania, 16802 (U.S.A.)

(Received September 8th, 1969)

Addition of Grignard reagents to unconjugated carbon–carbon multiple bonds, not ordinarily observed even under extreme conditions, is found in two special situations, Intramolecular addition, observed first by Roberts and his coworkers in a study of reversible cyclization of the 3-buten-1-yl Grignard reagent[1], has since been found to occur not only in a variety of Grignard reagents containing alkene functions[2,3], but also in reagents containing alkyne[4,5] and allene[6] functions. Addition to alkenols, first noted by Eisch and Husk[7] for addition of an allyl Grignard reagent to a substituted 3-buten-1-ol, has since been found in reactions[8] of allyl and benzyl Grignard reagents with allyl alcohols[★]; the hydroxyl function must promote addition, though the nature of this promotion has not been clear[★★].

We have now observed that the hydroxyl function promotes addition of Grignard reagents to alkynes. This communication reports examples of ready addition to primary alkynols of the allyl and also of the vinyl Grignard reagent. An adjoining communication by Eisch and Merkley reports additions of the allyl Grignard reagent to tertiary alkynols[10]. These additions provide another synthetic route to tri- and tetra-substituted olefins. The stereochemistries of the olefin products may reflect the stereochemical course of the addition of the elements (R and MgX) of a Grignard reagent to a multiple bond.

Dienol I[★★★] was isolated in 75% yield after refluxing allylmagnesium chloride[★★★★] and 2-butyn-1-ol in tetrahydrofuran for 4 hours and in 60% yield[★★★★★] after refluxing the reagents in ether for 4 hours. Conjugated dienol III was isolated in 60% yield after refluxing 2-butyn-1-ol and vinylmagnesium chloride in tetrahydrofuran for 24 hours. No addition products were observed and starting material was recovered in good yield from similar

---

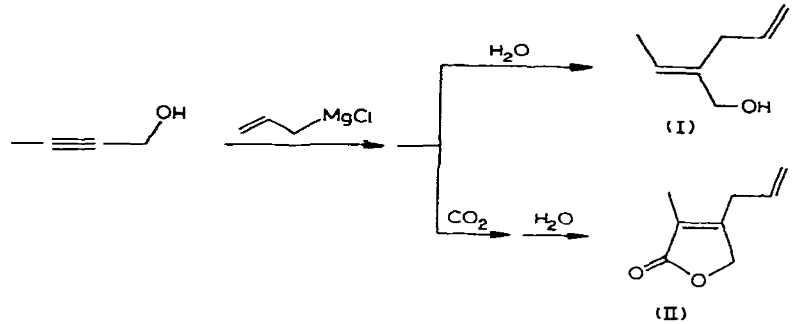
[★] Alkyllithium reagents also add more readily to allyl alcohols than to unsubstituted alkenes[9].

[★★] The molar ratio of organometallic to alkenol or alkynol exceeds 2 in the reactions discussed in this communication.

[★★★] The infrared and NMR spectra of the new compounds (I–VI) are in accord with the assignments of structure.

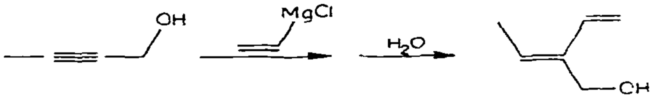
[★★★★] Ordinary Grignard grade magnesium was used in the particular experiments described in this communication.

[★★★★★] The reported yields are of quantities actually distilled from the reaction mixtures and are not corrected for alkynol recovered from each reaction.



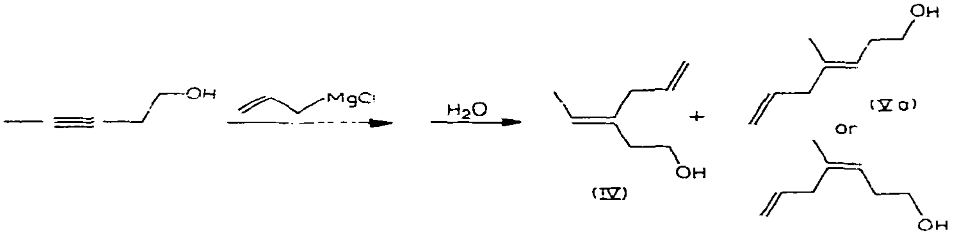
(I)

(II)



(III)

reactions with phenylmagnesium bromide in refluxing ether and with methylmagnesium chloride and with tert-butylmagnesium chloride in refluxing tetrahydrofuran. A mixture

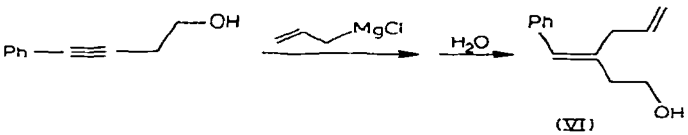


(IV)

(Va)

(Vb)

of dienols (IV and Va or Vb) was isolated in 30% yield after refluxing allylmagnesium chloride and 3-pentyn-1-ol in ether for 4 hours. The structural isomers (IV and V), separated by GLC, were present in approximately equal amounts. A similar reaction of 4-phenyl-3-butyn-1-ol furnished 40% of a single dienol (VI).

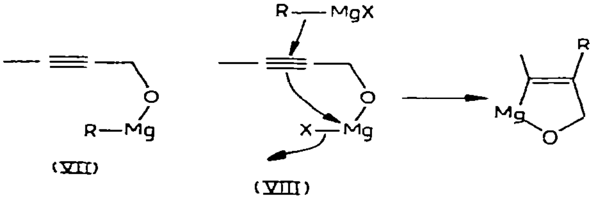


(VI)

Only one of the pair of *cis* and *trans* isomers of each structure seemed to be present in the isolated hydrolysis product.

The stereochemistries of the isolated products probably correspond to those of the vinyl Grignard reagents formed during the additions. Though the vinyl Grignard reagents conceivably could have undergone *cis–trans* isomerization after their formation, other vinyl Grignard reagents isomerize only slowly, if at all, under comparable conditions[11].

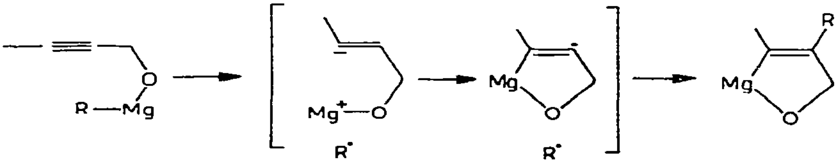
The assignment of configuration I is based on the isolation of a lactone (II) as the only new product from carbonation of a reaction solution★. By analogy, tentative assignments of configurations III, IV, and VI are made to the other products formed by addition of the organic residue of the Grignard reagent to the alkyne carbon nearer to the hydroxyl function. The NMR absorptions of hydrogens of equivalent functions in this group of products (I, III, IV, and VI) are very similar. No features of the NMR or infrared spectra of V, a product of addition of the organic residue to the alkyne carbon farther from the hydroxyl function, seem considerably more in accord with one than with the other of the possible configurations (Va or Vb)★★.



(VII) (VIII)

The hydroxyl function, essential in promoting these additions, must be coordinated with magnesium in the reaction solutions. It was proposed by Eisch and Husk[7] that the organic group (R) that will be added is first attached to the coordinated magnesium, as illustrated in VII for 2-butyn-1-ol; an addition proceeding through VII could be analogous to the additions in alkenyl, alkynyl and allenyl Grignard reagents that are favored by intramolecularity[2]. Alternatively, it has been suggested[8] that the additions may be intermolecular, the coordinated magnesium facilitating the addition of R of an external Grignard reagent, perhaps by acting as an electrophile, as illustrated in VIII for 2-butyn-1-ol.

Trans addition of R and of magnesium is tentatively indicated in this study for a reaction in which R becomes attached to the alkyne carbon nearer the hydroxyl group. *Trans* addition would be reasonable for an intermolecular mechanism such as indicated in VIII, though close approach of the magnesium to the farther alkyne carbon to which it ultimately becomes bonded would require considerable distortion. Addition could proceed instead by intramolecular reactions of species such as VII. The mechanism of such intramolecular additions probably would involve stepwise formation of the new C—C and C—Mg bonds - simultaneous *trans* (or *cis*) addition of R and of Mg to form those products in which R becomes attached to the alkyne carbon nearer the hydroxyl group would be difficult sterically★★★. The formation of the new C—Mg bond to the already coordinated magnesium at some stage of a multistep mechanism, for example an electron transfer mechanism that also is presented by Eisch and



★Carbonation of vinyl Grignard reagents is reported to proceed with considerable retention of stereochemistry[11].

★★Attempts to assign configurations to I, IV, and V by nuclear Overhauser experiments were inconclusive.

★★★A similar problem has been discussed for intramolecular cyclizations in alkenyl and alkynyl Grignard reagents[2,4,12]

Merkley[10], could fix the stereochemistry of an intermediate, leading to the observed *trans* addition. Eisch and Merkley believe that those products (such as V) in which R is attached to the alkyne carbon farther from the hydroxyl group form by *cis*-addition[10]. Though a simultaneous intramolecular *cis* addition in species similar to VII to form such products is sterically feasible, they also conclude that such additions may be stepwise★.

ACKNOWLEDGEMENTS

We are grateful to Professor John J. Eisch for generously delaying the publication of a related study (see adjoining communication) so that our work could be published at the same time. We thank Professor L.M. Jackman for a helpful discussion. We are grateful for support of this research by the Petroleum Research Fund and by the National Science Foundation and for aid in the purchase of NMR spectrometers by the National Science Foundation.

REFERENCES

1 M.S. Silver, P.R. Shafer, J.E. Nordlander, C. Rüchardt, and J.D. Roberts, *J. Amer. Chem. Soc.*, 82 (1960) 2646; further studies of 3-buten-1-yl reagents have since been reported: D.J. Patel, C.L. Hamilton and J.D. Roberts, *J. Amer. Chem. Soc.*, 87 (1965) 5144; M.E.H. Howden, A. Maercker, J. Burdon and J.D. Roberts, *J. Amer. Chem. Soc.*, 88 (1966) 1732; A. Maercker and J.D. Roberts, *J. Amer. Chem. Soc.*, 88 (1966) 1742.
2 H.G. Richey, Jr. and T.C. Rees, *Tetrahedron Lett.*, (1966) 4297.
3 E.A. Hill, H.G. Richey, Jr. and T.C. Rees, *J. Org. Chem.*, 28 (1963) 2161; T.C. Rees, Ph.D. Thesis, The Pennsylvania State University, 1966; H.G. Richey, Jr. and W.C. Kossa, Jr., unpublished observations.
4 H.G. Richey, Jr. and A.M. Rothman, *Tetrahedron Lett.*, (1968) 1457.
5 H.G. Richey, Jr. and A.M. Rothman, unpublished observations.
6 H.G. Richey, Jr. and W.C. Kossa, Jr., *Tetrahedron Lett.*, (1969) 2313.
7 J.J. Eisch and G.R. Husk, *J. Amer. Chem. Soc.*, 87 (1965) 4194.
8 M. Chérest, H. Felkin, C. Frajerman, C. Lion, G. Roussi and G. Swierczewski, *Tetrahedron Lett.*, (1966) 875.
9 J.K. Crandall and A.C. Clark, *Tetrahedron Lett.*, (1969) 325.
10 J.J. Eisch and J.H. Merkley, *J. Organometal. Chem.*, 20 (1969) P27.
11 G.J. Martin and M.L. Martin, *Bull. Soc. Chim. France*, (1966) 1636, and references cited therein.
12 H.G. Richey, Jr., in J. Zabicky (Ed.), *Chemistry of the Alkenes, Vol. 2*, Interscience, New York, Chapter 2, in press.

★Formation of the first bond in a stepwise addition leading to a product in which R is attached to the farther carbon would not fix the stereochemistry.