

interpreted if pyrrolylmagnesium chloride is represented as the N-MgX derivative I or the ionic, but not necessarily highly dissociated, resonance hybrid II.

Although a clear choice between these two alternatives cannot be made at this time, it should be pointed out that the lack of complete identity of the n.m.r. spectra of pyrrolylmagnesium chloride and the presumably ionic<sup>15</sup> pyrrolysodium (see chemical shift data) need not argue against the ionic structure II, since these differences might simply be due to variations in the solvation or degree of association of the two metals. Hopefully, studies which are presently underway in this laboratory to clarify this point will also shed some light on the marked differences in the chemical reactivity of the Grignard reagents<sup>9</sup> and alkali metal salts<sup>16</sup> of pyrrole.

**Acknowledgment.**—This research was supported by grants from the research committee of the University of California.

(15) L. Pauling, "The Nature of the Chemical Bond," Cornell University Press, Ithaca, N. Y., 1960, p. 93.

(16) C. F. Hobbs, C. K. McMillin, E. P. Papadopoulos, and C. A. VanderWerf, *J. Am. Chem. Soc.*, **84**, 43 (1962).

(17) Lockheed Graduate Research Fellow in Chemistry, summer, 1963.

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RECEIVED JULY 23, 1963

### Solvent Effect on *cis-trans* Isomerization in Grignard Reagent Formation from $\beta$ -Bromostyrenes

Sir:

We have found that a Grignard reagent prepared in the dark from *cis*- or *trans*- $\beta$ -bromostyrene shown to be free from the counter isomer of the bromide by infrared and n.m.r. spectra gives a mixture of *cis*- and *trans*- $\beta$ - $d_1$ -styrenes by addition of heavy water as can be seen in Fig. 1 and in Table I. Though n.m.r. signals due to the  $\beta$ -protons of  $\beta$ - $d_1$ -styrenes overlap with  $\beta$ -proton signals<sup>1</sup> of styrene contained in the  $\beta$ - $d_1$ -styrene mix-

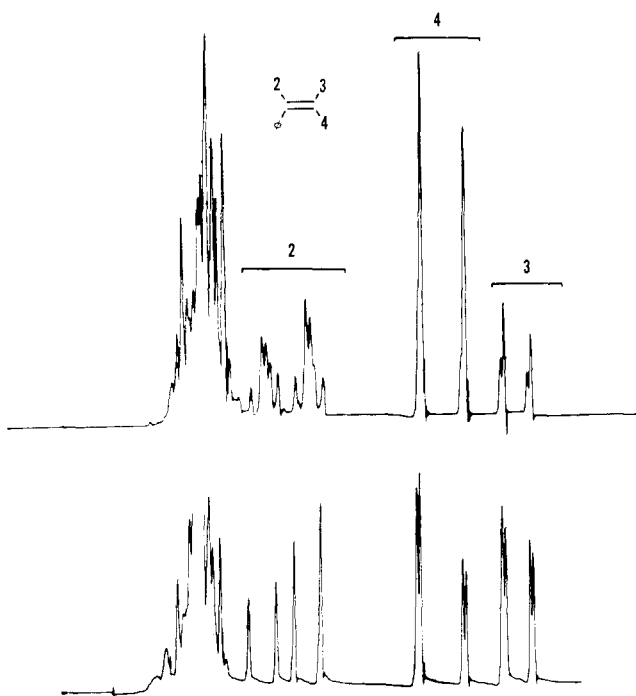


Fig. 1.—The n.m.r. spectrum (60 Mc.) of  $\beta$ - $d_1$ -styrene mixture obtained by the addition of heavy water to the Grignard reagent prepared from *trans*- $\beta$ -bromostyrene in tetrahydrofuran. The n.m.r. spectrum of styrene is also given for comparison.

TABLE I

THE *cis/trans* RATIOS IN  $\beta$ - $d_1$ -STYRENE MIXTURES OBTAINED BY ADDITION OF HEAVY WATER TO GRIGNARD REAGENTS PREPARED<sup>a</sup> FROM *cis*- OR *trans*- $\beta$ -BROMOSTYRENE IN VARIOUS SOLVENTS

Solvent	From <i>cis</i> - $\beta$ -bromostyrene	From <i>trans</i> - $\beta$ -bromostyrene
Tetrahydrofuran	10:1	1:10
1:1 Mixture of THF and EE	10:1	1:5
Ethyl ether	...	1:1

<sup>a</sup> Bromostyrene in solvent was added to Mg metal in 90 min. at 26° and the mixture was stirred for 15 min.

ture, the highest and lowest field signals of the  $\alpha$ -proton quartet<sup>1</sup> of styrene are separate from the  $\alpha$ -proton signals of  $\beta$ - $d_1$ -styrenes as seen in an example shown in Fig. 1. We can, therefore, easily estimate the amount of styrene contained in the mixture and make a correction for the  $\beta$ -proton signals. The *cis/trans* ratios thus obtained for the  $\beta$ - $d_1$ -styrene mixtures from these corrected areas of the  $\beta$ -proton signals are shown in the Table.

The *cis/trans* ratios are higher for the products from *cis*- $\beta$ -bromostyrene than those from the *trans* compound. However, the ratios are dependent on the solvent species used for preparing the reagents. If the Grignard reagent is prepared from *trans*- $\beta$ -bromostyrene, the original *trans* configuration is much more completely preserved in the  $\beta$ - $d_1$ -styrene mixture with the reagent prepared in tetrahydrofuran than with the reagent prepared in ethyl ether. The use of a 1:1 mixture of tetrahydrofuran and ethyl ether as solvent affords a product with a *cis/trans* ratio intermediate between those for the single solvents, though the ratio for the mixed solvent is closer to that for tetrahydrofuran. If a Grignard reagent is prepared from *cis*- $\beta$ -bromostyrene using tetrahydrofuran or the 1:1 mixture as solvent, the  $\beta$ - $d_1$ -styrene mixture obtained is much more abundant in *cis*- $\beta$ - $d_1$ -styrene than in the *trans* isomer. *cis*- $\beta$ -Bromostyrene does not form a Grignard reagent in ethyl ether at temperatures up to the boiling point of the solvent. The yields of  $\beta$ - $d_1$ -styrene mixtures in the other cases were in a range of 30–50% based on  $\beta$ -bromostyrenes, when the Grignard reagents were prepared at 26°.

It can clearly be concluded from the following experiment that the isomerization and the solvent effect on it take place in the course of Grignard reagent formation but not in addition of heavy water. When the Grignard reagent prepared in ethyl ether from *trans*- $\beta$ -bromostyrene is diluted with tetrahydrofuran, the *cis/trans* ratio of  $\beta$ - $d_1$ -styrenes obtained is equal to that from the same Grignard reagent diluted with ethyl ether. The *cis/trans* ratio is also unchanged by dilution with ethyl ether of the Grignard reagent prepared in tetrahydrofuran from *cis*- or *trans*- $\beta$ -bromostyrene.

The *cis/trans* ratio is unchanged by the difference of time intervals up to 5 hr. at 20° between the Grignard reagent formation, the dilution by solvent, and the addition of heavy water. This experimental result and the high degree of retention of original *cis* or *trans* configuration in tetrahydrofuran show that the Grignard reagent is stable in tetrahydrofuran, in which prompt isomerization of vinylolithium reagents is reported<sup>2</sup> to take place.

If the temperature is allowed to rise to the boiling point of the solution in the preparation of the Grignard reagent, the yield of  $\beta$ - $d_1$ -styrene decreases. ( $\beta$ - $d_1$ -Sty-

(1) As for the assignment of proton signals of styrene, see J. A. Pople, W. G. Schneider, and H. J. Bernstein, "High-resolution Nuclear Magnetic Resonance," McGraw-Hill Book Co., Inc., New York, N. Y., 1959, p. 240.

(2) D. Y. Curtin and W. J. Koehl, *J. Am. Chem. Soc.*, **84**, 1967 (1962).

renes are not practically obtainable from *trans*- $\beta$ -bromostyrene at the elevated temperature, when tetrahydrofuran is used as solvent.) However the *cis*/*trans* ratios of  $\beta$ - $d_1$ -styrene mixtures remain almost unchanged.

Details will be reported in a later paper.

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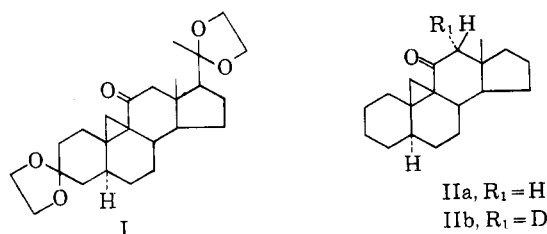
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RECEIVED MAY 25, 1963

### Spin-Spin Coupling between Hydrogen and Steroid Angular Methyl Protons

Sir:

Recently<sup>1</sup> it has been demonstrated that in certain fluorosteroids, spin-spin coupling between fluorine and angular methyl protons can occur. To our knowledge, only a single example of a split angular methyl resonance in a steroid nucleus not containing fluorine has been reported; *viz.* the C-18 methyl resonance in the n.m.r. spectrum of the 9,19-cyclo-11-keto steroid I occurred as a three-proton doublet ( $J = 0.7$  c.p.s.).<sup>2</sup> It was tentatively suggested that the splitting may be due to long-range coupling. We have observed a similar



coupling in the closely related ketone IIa and, furthermore, have demonstrated that the methyl protons are coupled to the C-12 axial ( $12\alpha$ ) proton. In the 100-Mc. n.m.r. spectrum<sup>3</sup> (Fig. 1a) of IIa, the C-18 methyl resonance

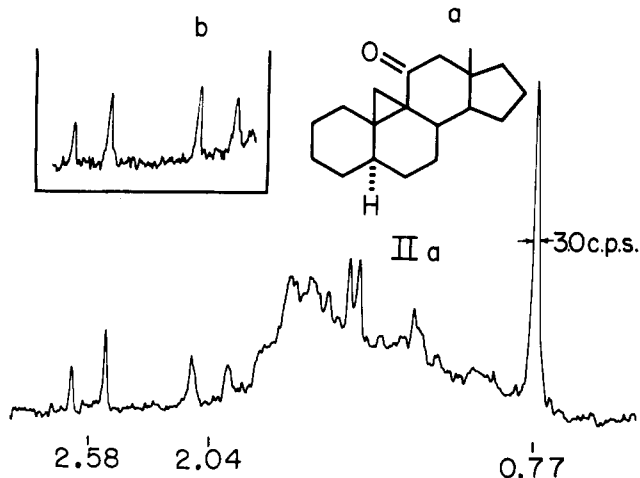


Figure 1.

at  $\delta = 0.77$  p.p.m., while not resolvable into a doublet, was broad (half-width = 3.0 c.p.s.). The downfield region of the spectrum showed a pair of doublets at  $\delta = 2.58$  and 2.04 p.p.m., due to the C-12 equatorial ( $12\beta$ ) and C-12 axial ( $12\alpha$ ) protons, respectively; the coupling constant of the two doublets ( $J = 15$  c.p.s.) is consistent with geminal coupling. Limited treat-

(1) A. D. Cross and P. W. Landis, *J. Am. Chem. Soc.*, **84**, 1736 (1962); *ibid.*, **84**, 3784 (1962).

(2) H. Wehrli, M. S. Heller, K. Schaffner, and O. Jeger, *Helv. Chim. Acta*, **44**, 2162 (1963).

(3) The n.m.r. spectra were obtained on a Varian HR-100 spectrometer. The samples were run as  $CDCl_3$  solutions with a trace of tetramethylsilane added to act as internal reference.

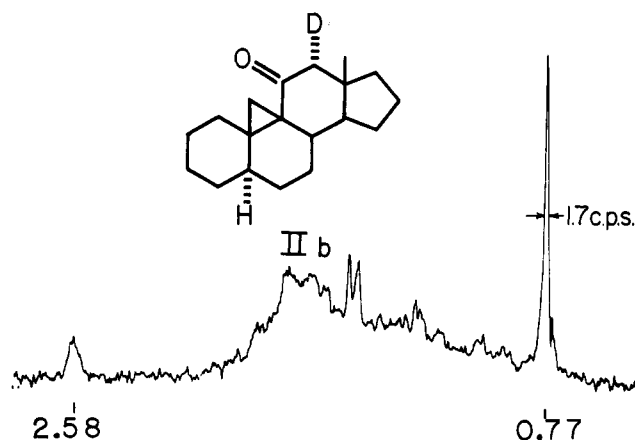


Figure 2.

ment<sup>4</sup> (0.5-hr. reflux) of IIa with base in deuterium oxide and deuteriomethanol gave the  $12\alpha$ - $d_1$ -9,19-cyclo-11-one (IIb) ( $d_0$ , 4%;  $d_1$ , 90%;  $d_2$ , 6% from mass spectral determination), the n.m.r. spectrum of which (Fig. 2) showed, as expected, no signals around  $\delta = 2.04$  p.p.m. and only a single resonance at  $\delta = 2.58$  p.p.m., broadened due to the small coupling of the C-12 equatorial proton with deuterium. In this spectrum, the half-width of the methyl resonance is now reduced to 1.7 c.p.s.; this is indicative of spin-spin coupling between the angular methyl protons and the C-12 axial hydrogen in IIa. Such a coupling was established conclusively by performing a double resonance experiment<sup>5</sup> on IIa. On double irradiation at the frequency of the methyl resonance, the doublet at  $\delta = 2.04$  p.p.m. was sharpened to give a symmetrical AB system (Fig. 1b), thus clearly demonstrating that the broadening of the C-12 axial proton resonance in the spectrum of IIa (Fig. 1a) is due to coupling with the methyl protons. Alternatively, double irradiation at the frequency of the C-12 axial proton again caused reduction in the half-width of the C-18 methyl resonance, as in the spectrum of the  $12\alpha$ - $d_1$ -ketone IIb (Fig. 2).

These results, and those described by us earlier,<sup>6</sup> along with the reported examples of allylic<sup>7</sup> and homo-allylic<sup>8</sup> coupling, again emphasize the caution which must be exercised in the interpretation of n.m.r. spectra.

**Acknowledgment.**—The work at Stanford University was supported by Grant No. CRTY-5061 from the National Institutes of Health of the U. S. Public Health Service.

(4) D. H. Williams, J. M. Wilson, H. Budzikiewicz, and C. Djerassi, *J. Am. Chem. Soc.*, **85**, 2091 (1963).

(5) N. S. Bhacca, M. E. Wolff, and R. Kwok, *ibid.*, **84**, 4976 (1962), and references cited therein.

(6) D. H. Williams, N. S. Bhacca, and C. Djerassi, *ibid.*, **85**, 2810 (1963).

(7) D. J. Collins and J. J. Hobbs, *Tetrahedron Letters*, **4**, 197 (1963), and references cited therein; T. A. Wittstruck, S. K. Malhotra, and H. J. Ringold, *J. Am. Chem. Soc.*, **85**, 1699 (1963).

(8) J. T. Pinhey, *Tetrahedron Letters*, **4**, 275 (1963).

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RECEIVED JULY 22, 1963

### Complexes of Organolithium Compounds with Vacant Orbital Acceptors

Sir:

Organo alkali metal compounds form donor-acceptor complexes with Lewis acids, such as diethylzinc, triethylaluminum, etc. We wish to report that properties, *e.g.*, bond energy, stoichiometry, and association