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DETERMINATION OF THE CONFIGURATIONS (CIS OR TRANS) OF ALKENOLS BY THE EFFECTS OF PARAMAGNETIC SHIFT REAGENTS ON THEIR NMR SPECTRA

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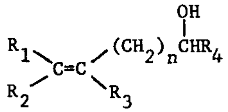
The configurations (*cis* or *trans*) of the members (7-20) of a group of alkenols (1), obtained, as described in the preceding communication,[1] from additions of Grignard reagents to



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alkynols, are critical to understanding the origin of the promoting effect of a hydroxyl group on these Grignard additions. The configurations of the alkenols can be assigned by considering the effect of a "shift reagent"[2] on the positions of their proton nmr absorptions. This method of assigning configurations is easily and rapidly carried out and is applicable even when only one member of a *cis*-*trans* pair of isomers is available.

This study had its basis in recent reports of induced shifts of nmr absorptions of organic molecules caused by coordinative bonding of a substituent with an unshared electron pair to a paramagnetic transition metal ion chelate.[2] The magnitudes of the induced shifts diminish with increasing distance between the coordinated transition metal and the proton giving rise to the nmr absorption.[4] Though conformational flexibility is a complicating factor, inspection of models indicates that the hydroxyl group and a transition metal complexed to that group on the average should be nearer to the *cis* substituent (R_1) than to an identical *trans* substituent (R_2) of 1. The chelate used was tris(2,2,6,6-tetramethylheptane-3,5-dionato)europium(III), found[3,6] to induce larger shifts than the corresponding dipyridine complex introduced originally by Hinckley.[5] In

Table. Ratios of Relative Changes of Positions of NMR Absorptions of R_1 and R_2 of Alkenols (1) Caused by *tris*(2,2,6,6-Tetramethylheptane-3,5-dionato)europium(III).[a]

	Name	R_1	R_2	R_3	R_4	n	θ_{R_1/R_2}[a,]
2	allyl alcohol	-H	-H	-H	-H	0	1.7
3	3-methyl-2-buten-1-ol	$-CH_3$	$-CH_3$	-H	-H	0	1.7
4	*trans*-2-buten-1-ol	-H	$-CH_3$	-H	-H	0	2.9
5	*cis*-3-hexen-1-ol	$-C\underline{H}_2CH_3$	-H	-H	-H	1	1.0
6	*trans*-3-hexen-1-ol	-H	$-C\underline{H}_2CH_3$	-H	-H	1	2.5
7	*cis*-4-methyl-3,6-heptadien-1-ol	$-C\underline{H}_2CH=CH_2$	$-CH_3$	-H	-H	1	1.7
8	*trans*-4-methyl-3,6-heptadien-1-ol[c]	$-CH_3$	$-C\underline{H}_2CH=CH_2$	-H	-H	1	1.6
9	*cis*-5-methyl-4,7-octadien-2-ol[c]	$-C\underline{H}_2CH=CH_2$	$-CH_3$	-H	$-CH_3$	1	2.3
10	*trans*-5-methyl-4,7-octadien-2-ol[c]	$-CH_3$	$-C\underline{H}_2CH=CH_2$	-H	$-CH_3$	1	1.8
11	*cis*-5-ethyl-4,7-octadien-2-ol	$-C\underline{H}_2CH=CH_2$	$-C\underline{H}_2CH_3$	-H	$-CH_3$	1	1.8
12	*trans*-5-ethyl-4,7-octadien-2-ol[c]	$-C\underline{H}_2CH_3$	$-C\underline{H}_2CH=CH_2$	-H	$-CH_3$	1	1.7
13	*cis*-4-ethyl-3,6-heptadien-1-ol	$-C\underline{H}_2CH=CH_2$	$-C\underline{H}_2CH_3$	-H	-H	1	1.9
14	*trans*-2-vinyl-2-buten-1-ol	-H	$-CH_3$	$-CH=CH_2$	-H	0	3.1
15	*trans*-2-allyl-2-buten-1-ol	-H	$-CH_3$	$-CH_2CH=CH_2$	-H	0	2.9
16	*trans*-3-allyl-3-penten-2-ol	-H	$-CH_3$	$-CH_2CH=CH_2$	$-CH_3$	0	3.0
17	*trans*-3-allyl-3-penten-1-ol	-H	$-CH_3$	$-CH_2CH=CH_2$	-H	1	2.5
18	*trans*-4-allyl-4-hexen-2-ol	-H	$-CH_3$	$-CH_2CH=CH_2$	$-CH_3$	1	2.4
19	*trans*-3-allyl-hexen-1-ol	-H	$-C\underline{H}_2CH_3$	$-CH_2CH=CH_2$	-H	1	2.7
20	*trans*-4-allyl-4-hepten-2-ol	-H	$-C\underline{H}_2CH_3$	$-CH_2CH=CH_2$	$-CH_3$	1	3.1

[a] The relative shifts reported here were obtained from carbon tetrachloride solutions ~0.68 M in alkenol and ~0.17 M in shift reagent.

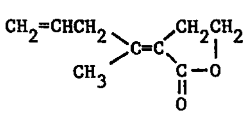
[b] This is the ratio of the change in the position of the absorption of R_1 caused by the shift reagent divided by that of R_2. When R_1 or R_2 contained more than one kind of proton, the absorption of the (underlined) methylene protons adjacent to the double bond were used.

[c] This compound was studied in a mixture containing its *cis-trans* isomer.

fact, in the nmr spectra of **2** and **3**,[7] model compounds in which $R_1 = R_2$ = H or CH_3, respectively, the induced shifts of the absorptions of R_1 were 1.7 times those of R_2. The data in the Table are expressed as θ, a ratio of two shifts, the subscripts indicating the functional groups giving rise to the absorptions being compared. Since, as noted in other studies,[3,8,9] the ratios show relatively little dependance on the molar ratio of shift reagent to substrate, meaningful values of θ can be obtained from the spectrum of a single solution in which the molar ratio is sufficient to lead to significant induced shifts. This procedure is less elegant than alternatives: (a) measuring the induced shift of each absorption as a function of the molar ratio and comparing the slopes of the lines,[10,11] and (b) comparing shifts obtained from solutions in which the molar ratio is 1.[9] However, the procedure used here is sufficient for the present purpose and obviates the need for preparing solutions in which the concentrations of the components are known accurately and from which water[11] and other impurities that would compete for the shift reagents are scrupulously excluded.

Compounds **7**-**12** are three pairs of <u>cis</u>-<u>trans</u> isomers in which one of the groups at R_1 and R_2 is allyl and the other is methyl or ethyl. The values of θ_{R_1/R_2} fall in the range 1.6-2.3 if configurations are assigned on the assumption that the shift of R_1 exceeds that of R_2. The value of $\theta_{C\underline{H}_2CH{=}CH_2/C\underline{H}_2CH_3} = 1.9$ of the single isomer of 4-ethyl-3,6-heptadien-1-ol indicates it to have the <u>cis</u> configuration (**13**). In compounds **14**-**20**, in which one of the groups at R_1 and R_2 is H and the other methyl or ethyl, the values of θ_{H/CH_2} and θ_{H/CH_3} fall in the range 2.4-3.1. Since the values for <u>trans</u> model compounds **4** and **6** fall within this range while, as expected, the value for <u>cis</u> model compound **5** is much lower, **14**-**20** are assigned <u>trans</u> configurations.

The configurational assignments in the Table are consistent with other information that is available about some of these compounds. A Grignard solution, resulting from a reaction of 3-pentyn-1-ol and allylmagnesium chloride, that furnished **7** and **17** on hydrolysis, furnished lactones **21** and **22**, rather than hydroxy acids on carbonation. Lactone **22** can have only the configuration shown, and the configuration of **17** presumably is the same. The configuration of **15** was earlier established in the same manner.[12] On the basis of an assumption about which isomer should



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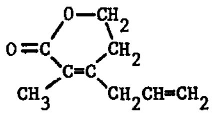

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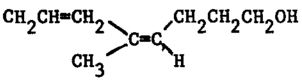

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dominate in the acid-catalyzed ring-opening of a substituted cyclopropylcarbinol used to generate the central double bond, the same configurations as in the Table have been assigned to **7** and **8**.[13] Some close similarities were noted between chemical shifts and coupling constants in nmr spectra of similar alkenols to which the same configurations were assigned. For example, the methyl absorption of *cis* isomers **7** and **9** was at δ1.68 (d, J $\simeq$ 1.5 Hz) but that of **8** and **10** was at 1.60 (d, J $\simeq$ 1.0 Hz). The observation that the methyl absorption of the single available[1] isomer of 5-methyl-4,7-octadien-1-ol was at δ1.68 (d, J $\simeq$ 1.5 Hz) permits a tentative assignment of a *cis* configuration (**23**).

The observation that values of θ_{R_1/R_2} (for a given R_1 and R_2) remain relatively constant in a series of alkenols in which other structural features change suggests that such empirical values may be generally useful in determining configurations of alkenes containing a function group capable of complexing with a shift reagent.[14]

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