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STEREOHETEROTOPICITY AND STEREOISOMERISM IN HETEROCHIRAL *CIS vs. TRANS* OLEFIN METAL π COMPLEXES

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SUMMARY. *The topic relationship of vinyl protons and the occurrence of stereoisomerism in heterochiral cis/trans olefin metal* π *complexes is analyzed by the didactically & heuristically useful concept of stereoheterotopicity. Predictions are verified by experiments.*

The concept of stereoheterotopicity introduced by Raban & Mislow in 1967[1] provides a significant tool for the prediction of spectroscopic nonequivalence (*e.g.* chemical shift anisochrony) and/or recognition of differences in chemical reactivity (*e.g.* substitution reactions at prostereogenic centers and addition reactions at prostereogenic faces).

We have previously analyzed[2] the stereotopic relationships between homomorphous atoms & olefinic faces which arise when an achiral moiety (*e.g.* an $Fe(CO)_4$ group) is π bonded to a *trans* or *cis* 1.2-disubstituted ethylene in which the constitutionally identical chiral ligands are configurationally equivalent (*homochiral*[2]) or nonequivalent (*heterochiral*[2]).

Thus, it has been demonstrated experimentally[2] that metal π complexation to the homotopic faces of homochiral di-l-menthyl maleate 1 (C_2 axis in the molecular plane) containing homotopic vinyl protons gives rise to the homomers 1a = 1b (*point group* C_1) in which the vinyl protons are internally diastereotopic, whereas metal π complexation to the diastereotopic faces of homochiral di-l-menthyl fumarate 3 (C_2 axis $\perp$ to the molecular plane) containing homotopic vinyl protons gives rise to diastereoisomers 3a&b (*point group* C_2) in which the vinyl protons remain internally homotopic but are rendered externally diastereotopic (cf. SCHEMES I & II).

It has been pointed out[2] that in *heterochiral* isomers the relationship between *internal* and *external*[3] diastereotopism and *cis/trans* geometry is reversed. Thus, in heterochiral di-d,l-menthyl maleate 2 (σ plane $\perp$ to the molecular plane, C_s) the vinyl protons are enantiotopic but the olefinic faces are diastereotopic. After metal π complexation two achiral (*meso*) diastereoisomers 2a&b (C_s) are formed [containing a stereogenic & achirotopic[4] ('pseudoasymmetric'[5]) metal center] in each of which the vinyl protons are internally enantiotopic but externally diastereotopic.

In heterochiral di-d,l-menthyl fumarate 4 (molecular center of symmetry, C_i) the vinyl protons & the olefinic faces are both enantiotopic. After metal π complexation enantiomers 4a&b (C_1) are formed in each of which the vinyl protons are internally diastereotopic (cf. SCHEMES I & II).

In a non-racemic chiral environment, *e.g.* in the presence of $Eu(TFA\text{-}1R\text{-}Cam)_3$[6], enantiotopic relationships are rendered diastereotopic. Thus, an overall diastereotopic relationship of the vinyl protons arises by the stepwise desymmetrization of fumaric acid (C_{2h}) and maleic acid (C_{2v}) *via* heterochiral esterification, π complexation and a chiral auxiliary (cf. SCHEME I).

Here we provide evidence for the predicted stereoheterotopicity and stereoisomerism in *heterochiral* olefin metal π complexes.

SCHEME I. Stereochemical Analysis of *homochiral/heterochiral vs.Z/E 1.2*-Disubstituted Ethene Tetracarbonyl Iron π Complexes [R=$-CO_2$(3-Menthyl)] and ^{1}H-NMR of the Vinyl Protons

Geometry	Z (*cis*)		E (*trans*)	
Chirality	*homochiral*	*heterochiral*	*homochiral*	*heterochiral*
H^1/H^2 & H$^{1'}$/H$^{2'}$ (*internal*)	diastereotop	enantiotop*	homotop	diastereotop
ν_H(ppm)($CDCl_3$)	3.36 3.45 AB	3.37 s 3.39 s	3.67 s 3.78 s	3.69 3.71 AB
H^1/H$^{2'}$ & H$^{1'}$/H^2 (*external*)	homotop	diastereotop	diastereotop	enantiotop*
Isomerism	HOMOMERS	*achiral* DIASTEREOISOMERS	*chiral* DIASTEREOISOMERS	ENANTIOMERS

*diastereotopic in a chiral environment (*e.g.*, *non-racemic* NMR shift reagent[7])

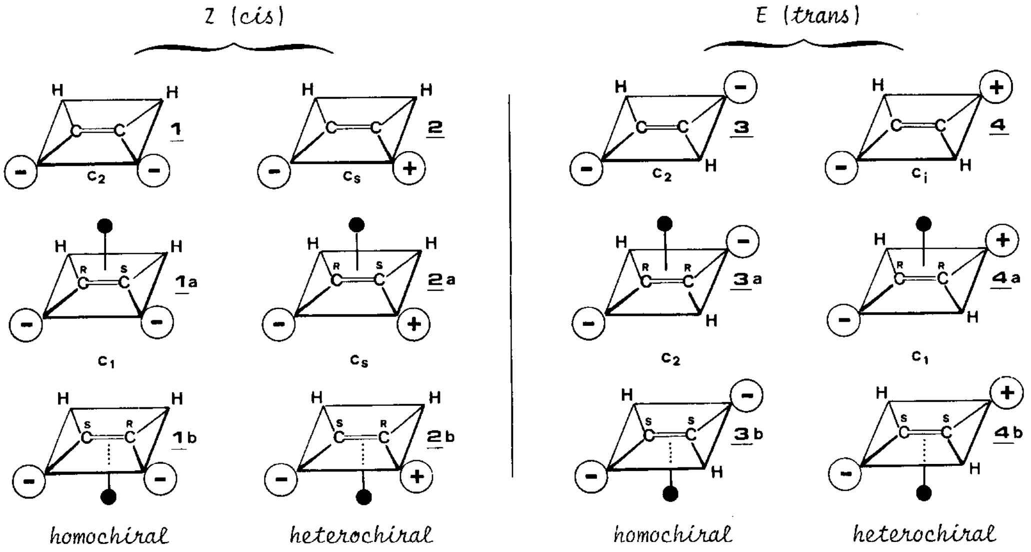
The 90 MHz ^{1}H-NMR spectrum of the crude reaction product of di-d,l-menthyl maleate 2[8] and $Fe_2(CO)_9$[9] exhibits two single lines of unequal intensity for the vinyl protons (3.37 & 3.39 ppm, 3:1)(cf. FIG. Ia), indicating the formation of two achiral (*meso*) diastereoisomers 2a&b. The major isomer (mp. 112°C, dec., optically i.a.) has been isolated from n-hexane and its absolute configuration 2a determined by a preliminary X-ray crystallographic analysis[10] (cf. FIG. Ib). Thus, preferential metal π complexation at one prostereogenic olefin face leads to the diastereoisomer 2a in which the vinyl protons resonate at higher field as compared to 2b. The internally enantiotopic vinyl protons are rendered internally diastereotopic (*AB system*)[11] in the presence of Eu(TFA-*1R*-Cam)$_3$[6]. The stereochemistry of heterochiral 2a&b is reminiscent to that of a heterochirally 1.2-disubstituted ferrocene compound[12], containing a stereogenic and achirotopic[4] ('pseudoasymmetric'[5]) metal center.

The 90 MHz ^{1}H-NMR spectrum of the reaction product of di-d,l-menthyl fumarate 4[8] and $Fe_2(CO)_9$[9] shows one single line for the vinyl protons which is split into two lines in the presence of Eu(TFA-*1R*-Cam)$_3$[6] (external diastereotopism[11]), indicating the formation of enantiomers 4a&b[13] (mp. 46°C). The (unexpected) occurrence of a single line for the internally diastereotopic vinyl protons is due to 'accidental isochrony' at 90 MHz. Indeed, by the recent availability of 400 MHz ^{1}H-NMR spectrometers a minute chemical shift difference of 0.025 ppm for the diastereotopic vinyl protons, giving rise to an *AB* quartet (cf. FIG. II: ν_{H_A}=3.685; ν_{H_B}=3.710 ppm; $^3J_{trans}$=10.24 Hz), could be observed.

In conclusion, all stereochemical relationships summarized in SCHEME I have now been confirmed by the experiment. Stereoisomeric olefin metal π complexes arising from *homo-/heterochiral* disubstitution and *cis/trans* geometry exhibit distinct chemical shift patterns in their ^{1}H-NMR spectra. Thus, *e.g.*, the absence of the homochiral transesterification products 1 and 3 in the synthesis[8] of 2 and 4 (as well as the presence of quantitative *cis-trans* isomerization of 5 to 4[8]) is evident from the ^{1}H-NMR spectra of the olefin metal π complexes 2 a&b and 4 a&b (cf. FIGs. I & II).

The present analysis is also valid for all organic compounds which may formally be regarded as addition products of atoms, or groups of atoms, to the double bond (cyclopropanes, oxiranes etc) as well as higher ring homologs of proper chiral disubstitution.

SCHEME II. Schematic Representation of Disubstituted Heterochiral *vs.* Homochiral and *cis* *vs.* *trans* Ethene Metal π Complexes[14]



● = Fe(CO)$_4$ (*fluxional*) ⊖ = -CO$_2$(l-(3*R*)-Menthyl) ⊕ = -CO$_2$(d-(3*S*)-Menthyl)

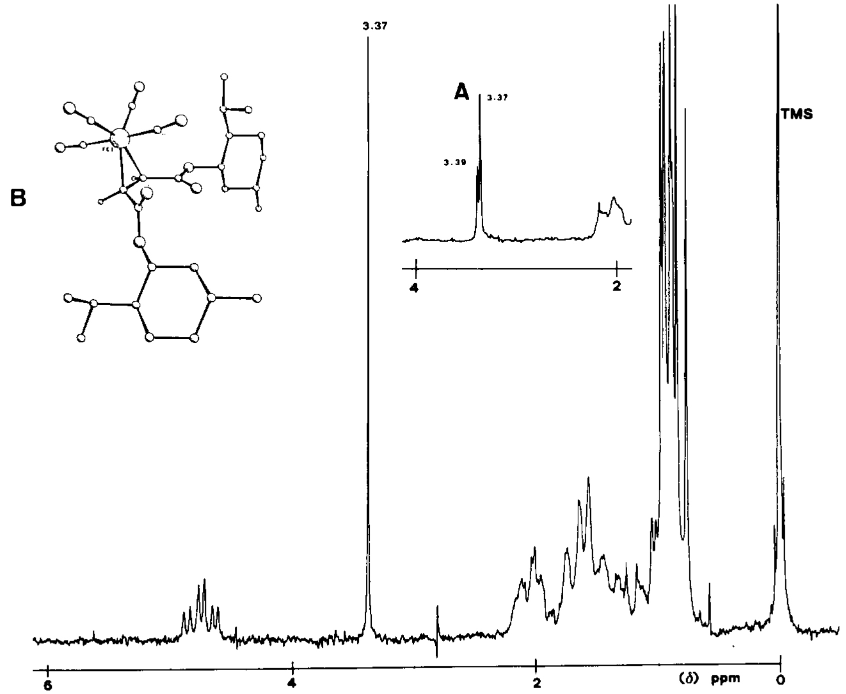


FIG. I: 90 MHz ^{1}H-NMR spectrum (CDCl$_3$, 25°C) of 2a (ν_H = 3.37 ppm), mp. 112°C, optically inactive

A: Mixture of 2 a&b (3 : 1) (ν_H = 3.37 & 3.39 ppm)

B: Single Crystal X-Ray Structure of 2a[10]

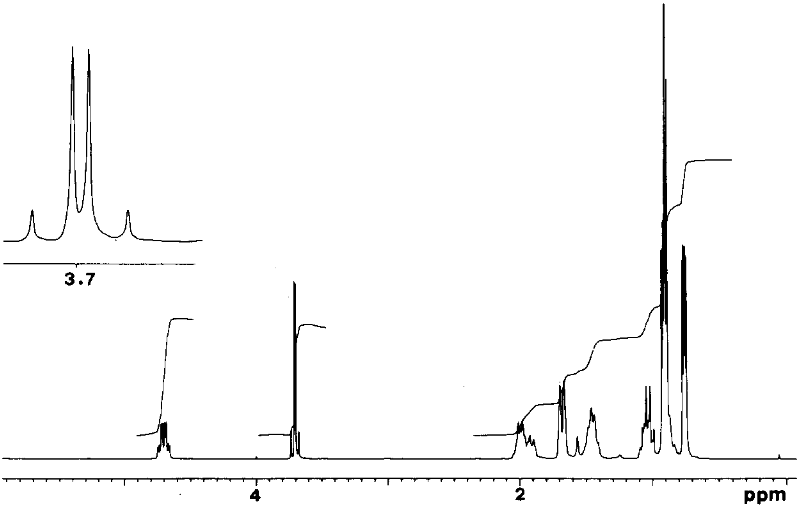


FIG. II: 400 MHz ^{1}H-NMR spectrum (CDCl$_3$, 25°C) of 4 a&b (enantiomers) (ν_{H_A} = 3.685 ppm, ν_{H_B} = 3.710 ppm, $^3J_{trans}$ = 10.24 Hz, AB quartet extended)

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3 The distinction between *internal* and *external* topic relationships [1] is, for NMR purposes, 'more a matter of convenience than of principle' (J.Reisse, R.Ottinger, P.Bickart and K.Mislow, J.Amer.Chem.Soc., 100, 911 (1978))

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5 V.Prelog und G.Helmchen, Angew.Chem., 94, 614 (1982), Angew.Chem.Int.Ed.Engl., 21, 567

6 Europium(III)*tris*(3-trifluoroacetyl-*1R*-camphorate)(V.Schurig, Tetrahedr.Lett., 1972, 1450)

7 cf. internal/external diastereotopism of vinyl protons in dimethyl maleate/fumarate tetracarbonyl iron π complexes in a chiral environment: V.Schurig, Tetrahedr.Lett., 1976, 1269

8 Starting material for heterochiral 2 *and* 4 is mono-l-menthyl maleate 5 (A.Wassermann, Ann., 488, 211 (1931). Thus, treatment of 5 with d-menthol in benzene with TosOH as catalyst gives 2 (mp. 78°C, ν(H)=6.19 ppm) whereas treatment of 5 with SOCl$_2$, pyridine and d-menthol in benzene yields 4 (mp. 105°C, ν(H)=6.83 ppm) via *cis/trans* isomerization.

9 The olefin tetracarbonyl iron π complexes 2 a&b and 4 a&b were prepared acc. to: E.Weiss, K.Stark, J.E.Lancaster and H.D.Murdoch, Helv.Chim.Acta, 46, 288 (1963)

10 W.Winter and V.Schurig, to be published

11 Note that the topic relationships apply also to other homomorphous atoms lying off the symmetry elements

12 S.I.Goldberg and W.D.Bailey, J.Amer.Chem.Soc., 96, 6381 (1974)

13 The enantiomeric relationship between 4a and 4b in SCHEME II is evident by 180° rotation around the olefin metal bond axis of one molecule in respect to the other.

14 *Cis-trans* isomerization in *homochiral* olefins ($1 \rightarrow 3$) displaces the C$_2$ axis by 90° and in *heterochiral* olefins ($2 \rightarrow 4$) changes the plane of symmetry into a center of symmetry. The stereotopic relationship of the vinyl protons and the occurrence of stereoisomers is clearly evident when the chirality symbols of the ferracyclopropane units (*R vs. S*) and the menthyl groups (+,-) in the π complexes are compared.

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