$^{13}C/^{1}H$ LONG RANGE COUPLING IN CONFIGURATION ASSIGNMENT OF TRI-SUBSTITUTED ALKENES

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Abstract. *The configuration of 1,1,1-trihalo-substituted 4-ethoxy-3-methyl-3-butene-2-ones is established definitively on the basis of a comparative study of $^{13}C/^{1}H$ long-range coupling constants.*

In the course of a systematic preparative study of the haloacetylation of enol ethers,[1] the problem arose of assigning the stereochemistry of the following α,β-unsaturated ketones:

$X_3C{-}C(=O){-}C(CH_3){=}CH{\sim}OCH_2CH_3$ (**A**) $X_3C{-}C(=O){\sim}CH{=}C(CH_3){-}OCH_3$ (**B**)

The usual assignment of *E/Z* configuration by the respective *cis* or *trans* $^{3}J(H,H)$ coupling naturally fails in the case of a tri-substituted olefin. The Karplus relationship still holds, though with different base values for 0° and 180°, for ^{3}J coupling between ^{13}C and ^{1}H.[2] As shown below, $^{3}J(C,H)$ coupling constants in the above structures are far too small for a definitive stereochemical assignment to be based on the numerical value alone, especially since, so far, one stereoisomer only was isolated in each case.[1]

$^{3}J(C,H)$ across an olefinic double bond generally is reduced by electronegative substituents X at the double bond (which is the case for **A** and **B**, X = OR), and increased by electronegative substitution at the sp^3 carbon end of the ^{3}J coupling pathway.[3] This seems to be restricted, though, to "normal" electronegative groups which as a rule bear lone electron pairs, *e.g.* $-\bar{O}-$ or $-\bar{N}<$, and thus may act as hyperconjugative electron donors. The electronegative CCl_3 and CF_3 moieties in the acylated enol ethers, in contrast, represent hyperconjugative electron acceptors, and so likewise reduce ^{3}J coupling. With only one stereoisomer available, the 2.5-3.5 Hz value, which is extremely small compared to analogous structures, *e.g.* O=C-C=CH-, in the literature,[4] cannot be applied as a direct stereochemical criterion. We now report the configurational assignment of the butenones **A**, based on the numerical values of corresponding C,H long-range coupling constants in model compounds with established geometry.

E-Configuration is unequivocally established for 1,1,1-trichloro-4-ethoxy-3-butene-2-one (**2a**) and 4-ethoxy-1,1,1-trifluoro-3-butene-2-one (**1a**) (the acylation products of ethyl vinyl ether) by the $^{3}J(3\text{-}H,4\text{-}H)$ coupling constant of 12.2 Hz which for this structure definitely connotes *trans*.[5] The carbonyl ^{13}C resonance of **1a** is split, in the first place, into a $^{2}J(^{19}F,^{13}C)$ quartet (35.0 Hz, see Figure 1a). Each of these quartet lines in turn is split into a dublet of dublets (3.3 and 2.3 Hz, respectively). Neither coupling constant can be directly assigned, though, to $^{2}J(C\text{-}2,3\text{-}H)$ or $^{3}J(C\text{-}2,4\text{-}H)$. Fortunately, the two protons in question are separated by more than 2 ppm (*i.e.* 625 Hz in a 300 MHz ^{1}H spectrum). Selective, low-power irradiation of each ^{1}H resonance demonstrates the smaller value, 2.3 Hz, to correspond to the geminal coupling $^{2}J(C\text{-}2,3\text{-}H)$ (see Figure 1c). With the configuration of **1a** definitely *E*, the 3.3 Hz coupling needs corresponds to a *cis* ^{3}J pathway (Figure 1b).

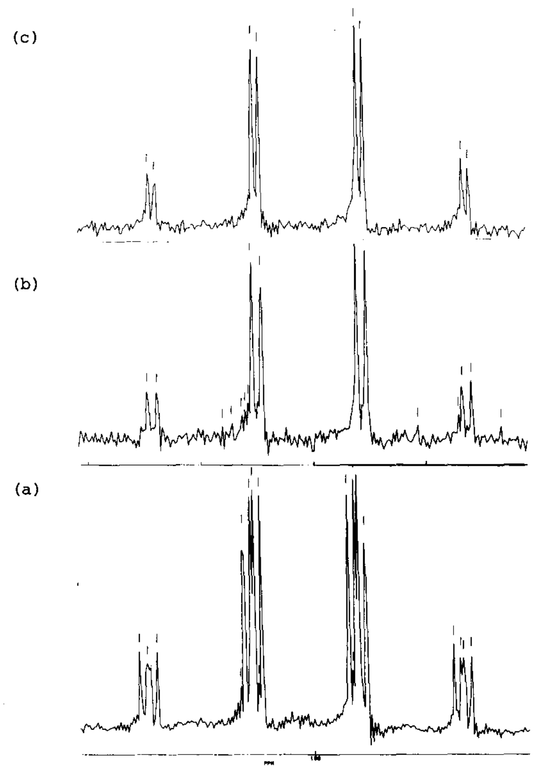
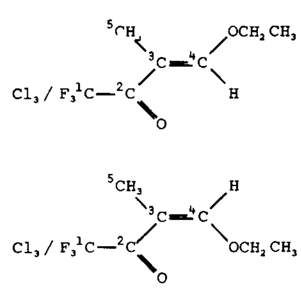


Figure 1. Carbonyl ^{13}C resonance (C-2) of (E)-4-ethoxy-1,1,1-trifluoro-3-butene-2-one (1a) (75.47 MHz, 0.5 M in $CDCl_3$, digital resolution 0.5 Hz/point):

(a) fully coupled, (b) with selective, low-power decoupling of 3-H, (c) ditto of 4-H

Trihaloacetylation of propenyl ethyl ether (1-ethoxypropene) affords 4-ethoxy-1,1,1-trifluoro-3-methyl-3-butene-2-one (1b) and the corresponding 1,1,1-trichloro derivative 2b. In this case, the ^1H NMR spectrum does not allow for a stereochemical differentiation between the two stereoisomers *C* and *D* (allylic coupling is no reliable criterion in a highly polarized, hetero-substituted alkene[6]).



C

1b/2b

D

The carbonyl (C-2) ^{13}C resonance of 1b shows the four lines of the primary $^2J(C,F)$ quartet each split into a pseudo-quintet, indicating ^3J coupling to 4-H and the methyl protons at C-5 to have more or less the same value. The following mean coupling constants are calculated from the individual, repetitive splittings within these multiplets which actually constitute superimposed dublets of quartets:

$^3J(C\text{-}2,CH_3)$ 3.9 Hz $^3J(C\text{-}2,4\text{-}H)$ 3.4 Hz.

These values are confirmed once again by selective, low-power decoupling (not shown). The 3.4 Hz vicinal C,H coupling in 1b is identical, within experimental error, with the 3.3 Hz for the established *cis*-^3J coupling in 1a. Consequently, 1b likewise must be assigned *E*-configuration (*i.e.* structure *C*). The methyl carbon (C-5), which in this case is *trans* to the lone olefinic proton, displays a ^3J coupling to 4-H of 5.3 Hz. The general rule that, within a given olefinic structure, $^3J(trans)$ generally is larger than $^3J(cis)$, once again seems to hold.

The ^{13}C spectra of the trichloroacetyl derivatives 2a and 2b are simplified by the absence of additional ^{19}F couplings. *E*-Configuration once more is established unequivocally for the ethoxy butenone 2a by virtue of the 12.0 Hz value for $^3J(3\text{-}H,4\text{-}H)$. The carbonyl (C-2) resonance appears as a genuine triplet in the fully-coupled ^{13}C spectrum, $^2J(C\text{-}2,3\text{-}H)$ and $^3J(C\text{-}2,4\text{-}H)$ apparently being more or less equivalent. The mean value of 2.8 Hz is 0.5 Hz smaller than in 1a.

If this reduction were to be effective also for 2b, as compared to 1b, the carbonyl resonance of 2b would no longer appear as a pseudo-quintet in the fully-coupled ^{13}C spectrum.

A proper quartet of dublets is in fact observed (see Figure 2a) whence the following coupling constants can be extracted:

$^3J(C\text{-}2,CH_3)$ 3.9_5 Hz $^3J(C\text{-}2,4\text{-}H)$ 2.8_5 Hz.

The value for the ^3J coupling to the methyl protons is identical with that for the corres-

(a)

(b)

(c)

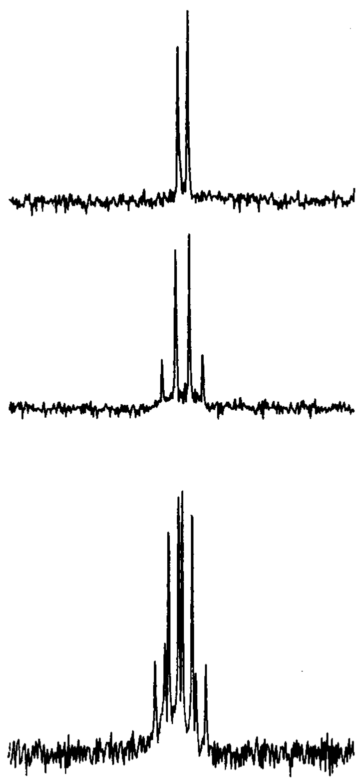


Figure 2. Carbonyl ^{13}C resonance (C-2) of (E)-1,1,1-trichloro-4-ethoxy-3-methyl-3-butene-2-one (2b) (75.47 MHz, 1.0 M in $CDCl_3$, digital resolution better than 0.03 Hz/point):

(a) fully coupled, (b) with selective, low-power decoupling of 4-H, (c) ditto of the CH_3 protons at C-5

ponding fluoro compound 1b, and the *cis*-^3J coupling constant appears indeed reduced by 0.5 Hz as predicted. For a double-check, the CH_3 protons as well as the residual olefinic proton were selectively decoupled. From these traces (Figure 2b,c), the same 2.8_5 and 3.9_5 Hz values are read off as from the fully-coupled spectrum.

The four 4-ethoxy-3-butene-2-ones, presented here, thus are all obtained from the acylation in *E*-configuration. (This is not the result of rearrangement during work-up since spectra run directly off the crude reaction mixtures show the same resonances.) This amazingly high configurational selectivity is probably due to the better push-pull resonance interaction, in the *E*-form, between $CX_3C{=}O$ acceptor and -$\bar{O}$-R donor group.

A full analysis of the ^1H and ^{13}C NMR data, especially with respect to the conformation about the C-3–$COCX_3$ and the O-CH_3/CH_2 single bonds, will be published separately.[7]

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