reaction vessel is maintained below 20 °C by cold water circulation. After 3 h, the solvent is evaporated under vacuo, and the product is isolated by using a silica gel column (1.5 × 10 cm): yield of **15**, 97 mg (66%); recovered benzothiet, 6 mg (10%).

A similar experiment with dimethyl acetylenedicarboxylate (**12**) gave **13** in 57% yield. The recovery of benzothiet was 22%.

Acknowledgment. Financial support to this work was provided by the Deutsche Forschungsgemeinschaft and the Fonds der Chemischen Industrie. We thank the Alexander von Humboldt Foundation for the award of a Fellowship to K.K.

Registry No. **3**, 63559-01-3; **6**, 59130-11-9; **9**, 496-31-1; **10**, 263-06-9; **11**, 84559-50-2; **12**, 762-42-5; **13**, 84559-51-3; **14**, 941-69-5; **15**, 66303-97-7; **16**, 96-33-3; **17**, 84559-52-4; **18**, 84559-53-5; **19**, 930-68-7; **20**, 84582-82-1.

Vicinal ^{13}C–^{13}C Coupling Constants as a Configurational Probe: Stereochemistry of the Base-Catalyzed Double Bond Shift in Proacacipetalin

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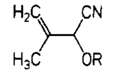
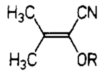
Received July 7, 1982

In recent years a considerable amount of information about ^{13}C–^{13}C spin–spin coupling constants has become available,[1] confirming their potential utility for solving stereochemical problems. Although observation of ^{13}C–^{13}C couplings usually requires ^{13}C-enriched materials, which prevents them from being routinely accessible at present,[2] the usefulness or even uniqueness of the stereochemical information provided by ^{13}C–^{13}C coupling constants may sometimes make their use attractive, especially when introduction of the necessary label is straightforward. We report a case belonging to this category.

Proacacipetalin (**1a**),[3] a natural glucoside occurring in *Acacia* species, undergoes isomerization in base to the conjugated isomer **2a**, acacipetalin.[3] The stereospecific nature of the isomerization became apparent when the reaction was carried out in deuterium oxide, which resulted[3] in incorporation of one deuterium atom per molecule of product exclusively into the more shielded (^{1}H and ^{13}C NMR spectra) of the two methyl groups of **2a**.[3] Similarly, **1b**, a synthetic analogue of proacacipetalin, is converted by base to **2b**, and isomerization in methanol-*d* yields a product containing one deuterium atom in the more shielded methyl group. However, unambiguous assignment of the methyl resonances in ^{1}H and ^{13}C NMR spectra of **2a** and **2b**, and thus a decision as to whether the deuterated products are the *Z* isomers **3a** and **3b** or the *E* isomers **4a** and **4b**, cannot be made immediately.



1



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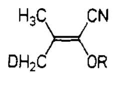
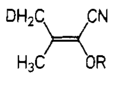


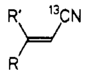
3



4

a R = β-D-glucopyranosyl
b R = 2-tetrahydropyranyl

Earlier studies on α,β-unsaturated carboxylic acids and esters indicated that vicinal ^{13}C–^{13}C coupling constants across a double bond may be suitable for differentiation between *E* and *Z* configurations.[4-6] That the relationship $^3J_{cis} < {}^3J_{trans}$, familiar for ^{1}H–^{1}H and also established for ^{13}C–^{1}H coupling constants,[7-9] is likewise valid for vicinal ^{13}C–^{13}C couplings to the nitrile group in α,β-unsaturated nitriles is now demonstrated by measurement of ^{13}C NMR spectra of **5–7** (Table I). The ratio $^3J_{cis}/{}^3J_{trans}$ for couplings either within the same molecule (**7**) or in an *E,Z* isomeric pair (**5** and **6**) is 0.5–0.6 and overlaps the range of 0.55–0.7 already established[10] for ^{1}**HC═CX** (X = ^{1}H, ^{13}C) couplings in ethene and propene and their monocyano derivatives. For ^{1}**HC═CX** couplings in monomethoxy and monoacetoxy derivatives of ethene and propene both $^3J_{cis}$ and $^3J_{trans}$ are substantially reduced, and their ratio appears to be slightly lower (0.4–0.5).[10] Synthesis of **2b** enriched with ^{13}C in the nitrile group and measurement of three-bond ^{13}C–^{13}C coupling constants to the methyl groups (Table I) show that the constants are reduced as expected compared with those of **7** by attachment of an oxygen atom to the double bond, for $^3J_{cis}$ is still clearly lower than $^3J_{trans}$, their experimental ratio being 0.6 rather than its reciprocal. Thus the high-field methyl resonance of **2b** (and consequently also that of **2a**) must be assigned to the methyl group trans to the nitrile group, and the deuterated



5 R=CH$_3$, R'=H
6 R=H, R'=CH$_3$
7 R=R'=CH$_3$

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Table I. ^{13}C NMR Chemical Shifts and $^nJ(^{13}C, ^{13}CN)$ Coupling Constants in α,β-Unsaturated Nitriles[a]

	chemical shifts, δ					coupling constants,[b] Hz			
compd	C1	C2	C3	CH_3 (cis[c])	CH_3 (trans[c])	^1J	^2J	$^3J_{cis}$	$^3J_{trans}$
5	116.6	100.1	151.1		18.4	79.1	<2		8.1
6	115.0	99.8	149.9	16.8		77.0	<2	4.7	
7	117.0	95.6	162.0	22.3	24.9	79.2	<2	3.8	7.6
2b[d]	114.1	122.7	136.2	20.3	17.5	91.6	8.2	2.4	4.1

[a] The spectra were obtained with ca. 1% solutions in deuteriochloroform, degassed by freeze-pump-thaw cycles, at 67.889 MHz and with a digital resolution of 0.1-0.2 Hz per data point. [b] Absolute values. [c] Cis and trans relative to the nitrile group. [d] Labeled with 90 atom % of ^{13}C in the nitrile group. The remaining resonances: δ 18.6 (C4′), 24.8 (C5′), 29.4 (C3′), 62.6 (C6′), 98.3 (d, $^3J = 1.5$ Hz, C2′).

products obtained from **1a** and **1b** have structures **3a** and **3b**, respectively. The stereospecific deuterium incorporation during the base-catalyzed double bond migration thus parallels the stereospecific base-catalyzed conversion of 2-propenyl ethers into (*Z*)-1-propenyl ethers.[11,12]

The magnitudes of the remaining ^{13}C–^{13}C coupling constants reported in Table I deserve a few additional remarks. The most noteworthy is the unusually large value of ^2J in **2b** as compared with those of **5**–**7**, which is due to the presence of the oxygen function; a similarly drastic increase of a $^2J_{CC}$ coupling constant was earlier observed in derivatives of propenoic acid on substitution with nitrogen.[5] The increase of ^1J in **2b** relative to **5**–**7** is likewise caused by oxygenation of the α-carbon and parallels similar substituent effects on $^1J_{CH}$.[8,9] The one- and three-bond coupling constants observed for the nitriles **5**–**7** are somewhat larger in absolute value than analogous ^{13}C–^{13}C couplings involving the carbonyl group in the corresponding α,β-unsaturated carboxylic acids.[4,6]

Experimental Section

3-Methyl-2-[(2-tetrahydropyranyl)oxy]-3-butenenitrile (1b) was obtained from 2-hydroxy-3-methyl-3-butenenitrile[13] and 3,4-dihydro-2*H*-pyran in the presence of traces of HBr. Distillation [bp 90–100 °C (ca. 10 mmHg)] gave a 1:1 mixture of two racemic diastereoisomers of **1b**: retention times of 4.8 and 5.4 min [3% OV-101 dimethylsilicone on Chromosorb W (80–100 mesh), 1.8 m × 2.4 mm i.d. steel column, at 140 °C and a nitrogen flow of 20 mL/min]; IR (film) ν_{max} 2245 (w) cm^{-1}; mass spectrum, *m/e* (relative intensity) 181 (1.5), 180 (1.5), 153 (5.5), 85 (100). The diastereoisomers could be partially separated by distillation, enabling assignment of the NMR signals. Diastereoisomer with shorter retention time: ^{1}H NMR ($CDCl_3$) δ 1.92 (CH_3), 4.96 (Hα, exchangeable for deuterium in base), 4.99 (H2′, t, $^3J \approx 3$ Hz[14]), 5.15 and 5.35 (olefinic protons), signals of the remaining protons at δ 1.5–1.9 and 3.5–3.9; ^{13}C NMR ($CDCl_3$) δ 18.5 and 18.7 (CH_3 and C4′), 25.2 (C5′), 29.8 (C3′), 62.3 (C6′), 67.3 (C2), 96.4 (C2′), 116.1 (C4), 116.9 (C1), 137.8 (C3).[15] Diastereoisomer with longer retention time: ^{1}H NMR ($CDCl_3$) δ 1.87 (CH_3), 4.73 (H2′, t, $^3J \approx 3$ Hz[14]),[16] 4.80 (Hα, exchangeable for deuterium in base),[16] 5.15 and 5.25 (olefinic protons), signals of the remaining protons at δ 1.5–1.9 and 3.5–3.9; ^{13}C NMR ($CDCl_3$) δ 17.7 and 18.3 (CH_3 and C4′), 25.2 (C5′), 29.8 (C3′), 61.9 (C6′), 68.5 (C2), 97.5 (C2′), 117.0 C4), 117.5 (C1), 137.6 (C3).[15]

3-Methyl-2-[(2-tetrahydropyranyl)oxy]-2-butenenitrile (2b) was obtained by isomerization of **1b** in 0.1 M methanolic NaOH at room temperature during 5–10 min (the half-life of **1b** under these conditions, measured spectrophotometrically, was about 30 s) and vacuum distillation [bp 60 °C (ca. 10 mmHg)]: IR (film) ν_{max} 2213 (s) cm^{-1}; UV (CH_3CN) λ_{max} 223 nm; mass spectrum, *m/e* (relative intensity) 181 (1.5), 85 (100); ^{1}H NMR ($CDCl_3$) δ 1.87 and 1.96 (methyl groups), 5.23 (H2′, t, $^3J \approx 3$ Hz[14]), signals of the remaining protons at δ 1.5–1.9 and 3.6–3.9; ^{13}C NMR, see Table I.[15]

When **1b** was converted to **2b** in methanol-*d* (99.5 atom % of deuterium), the product contained about 85 atom % of deuterium[17] (^{1}H NMR and mass spectra), all of which was present in the more shielded methyl group: ^{1}H NMR δ 1.85 ($|^2J_{HD}|$ 2.1 Hz), ^{13}C NMR δ 17.2 ($^1J_{CD} = 19$ Hz) (cf. deuterated **2a**[3]).

Labeled Compounds. Labeled **2b** was obtained as described above by starting with $K^{13}CN$ (90 atom % ^{13}C). The nitriles **5**–**7** were prepared by heating neat 3-bromopropene or 2-methyl-3-chloropropene with a 50 % molar excess of $K^{13}CN$ (90 atom % ^{13}C) at 130–140 °C in Teflon-sealed vials during 3–4 h and were used without purification. In the former case the product consisted of **5** and **6** in a 2:3 ratio (^{1}H NMR),[11c,18] the assignment of ^{13}C resonances (Table I) being based on spectra of pure 2-butenenitriles.

Acknowledgment. We are indebted to Dr. Kjeld Schaumburg (Chemical Laboratory V, University of Copenhagen) for recording ^{13}C spectra reported in this work on a Bruker HX-270S spectrometer, made available by the Danish Natural Science Research Council.

Registry No. **1a**, 66871-89-4; (±)-**1b** (isomer 1), 84499-47-8; (±)-**1b** (isomer 2), 84499-48-9; **2a**, 644-68-8; (±)-**2b**, 84499-49-0; (±)-**2b**-*1*-^{13}*C*, 84520-43-4; (±)-**3b**, 84499-50-3; **5**, 84499-51-4; **6**, 84499-52-5; **7**, 84499-53-6; $K^{13}CN$, 25909-68-6; (±)-2-hydroxy-3-methyl-3-butenenitrile, 84499-54-7; 3,4-dihydro-2*H*-pyran, 110-87-2; 3-bromopropene, 106-95-6; 2-methyl-3-chloropropene, 563-47-3; 3-butenenitrile-*1*-^{13}*C*, 84499-55-8.

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(16) Cf. the relationship between chemical shifts of anomeric and α hydrogens and GLC retention times of per-*O*-trimethylsilyl derivatives of proacacipetalin and epiproacacipetalin.[3]

(17) The proportion of undeuterated **2b** found suggests that some of the isomerization may have occurred by an intramolecular hydrogen shift.[11b]

(18) The crude mixture of **5** and **6** also contained the unconjugated isomer 3-butenenitrile-*1*-^{13}*C* [$\delta(^{13}C)$ 21.0 (C2), 117.1 (C1), 119.2 (C4), 125.5 (C3); in $CDCl_3$], the previously unreported ^{13}C–^{13}C couplings in which were $^1J = 57.7$ Hz, $^2J = 4.1$ Hz, and $^3J = 4.5$ Hz (absolute values).