Geminal and Vicinal ^{13}C–^{13}C Coupling Constants in Carboxylic Acid Derivatives

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Geminal ^{13}C–^{13}C coupling constants in αβ-unsaturated azlactones and the acids and esters derived from their hydrolysis are large and strongly dependent on configuration. Coupling constants in simple $^{13}C_1$-labelled carboxylic acids are also reported; vicinal couplings show a strong geometric dependence but the geminal couplings depend mainly on hybridisation.

THE assignment of the configuration of unsaturated azlactones such as (1a and b) and the esters derived from their hydrolysis has been extensively investigated.[1] Russian workers have recently devised an n.m.r. method based on the long-range coupling constant $^3J_{C(5)H\beta}$ between the carbonyl carbon and the olefinic H_β proton.[2] These couplings were found to be dependent on stereochemistry[3] with $^3J_{trans} > {}^3J_{cis}$ (12.5, 5.5 Hz). In connection with investigations into the mechanism of asymmetric hydrogenation[4] the doubly labelled compounds (1)—(4) were synthesised and the geminal carbon–carbon coupling constants determined (Table 1). It is clear from these data that the geminal coupling constants are dramatically affected by the substitution of an amido-group and are also strongly dependent on geometry. Thus, the coupling constants in the unsubstituted series might be expected to be of interest; the carboxy-labelled species (5)—(12) were therefore synthesised. Their chemical shifts and coupling constants are given in Tables 2 and 3. Where possible the two- and three-bond coupling constants to H(2) and H(3) were also measured and are given in Table 4.

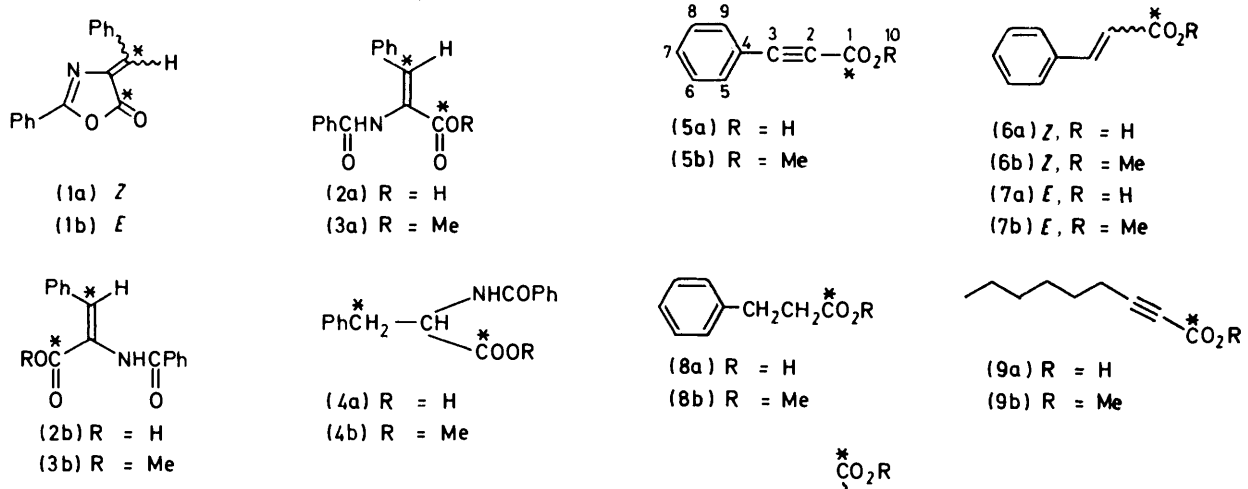
Geminal Coupling Constants.—Considering first (Table 1) the geminal coupling constants in the dehydroamino-acid derivatives (1)—(3) it is apparent that these are all substantially larger than those measured for simple unsaturated acids. The substitution of an electronegative atom at the central carbon atom in two-bond coupling is most likely to give a positive contribution to ^2J based on the precedent of [2-^{13}C]naphthalen-1-ol.[5] It has also been noted that $^2J_{C_1C_2}$ for 2-chloropropene is 4.6 Hz[6] whereas other simple olefins have coupling

TABLE 1

Chemical shifts [a] and coupling constants [b] in azlactone derivatives (1)—(4)

Compound	(1a) [c]	(1b) [c]	(2a)	(2b)	(3a)	(3b)	(4a)	(4b)
δC(1)	167.6	164.3	168.4	168.4	167.2	167.6	173.6	173.6
δC(3)	135.5	139.9	136.6	125.9	136.4	125.4	38.2	38.1
$^2J_{C(1)C(3)}$	7.8	7.7	5.5	3.4	5.6	3.4	*d*	*d*

[a] Chemical shifts were recorded in CD_3OD solution in p.p.m. downfield from external Me_4Si. [b] ±0.1 Hz. [c] CD_2Cl_2 as solvent. [d] Not observed, <0.6 Hz.



constants of 1 Hz or less. These geminal coupling constants are also dependent on the configuration of the double bond. Geminal coupling constants in polycyclic aromatic compounds bearing carbonyl groups have been extensively studied by Hansen and his co-workers [7] who demonstrated that the steric bulk of the group attached to the carbonyl substituent in a *peri*-position of a polycyclic aromatic system caused the observed diminution in coupling constant. Their results are exemplified by (13) and (14). Steric compression forces the substituted carbonyl group to twist out of the plane of the aromatic nucleus and they postulated that the consequent loss of conjugation has an important influence on the magnitude of the coupling constant.

The crystal structure of (2a) has been determined [8] but its atomic co-ordinates are not quoted and since the *R* factor is 18% little reliance can be placed on the detailed geometry. Crystal structure data for methyl *m*- and *p*-bromocinnamates [9] show that they adopt an *S-cis* configuration (15) whereas cinnamic acid (7a) adopts an *S-trans* configuration in order to accommodate intermolecular hydrogen-bonding. In (15) the angle of twist about C(1)–C(2) is small (<10°) in the solid state but in (16) the deviation is more marked with O(1) 0.241 Å out of the plane defined by C(1)–C(4).[10] The deviation from planarity is even more marked in the corresponding *cis*-acid (17). In both (1a and b) the five-membered ring imposes strict planarity on the unsaturated system.

TABLE 2

Chemical shifts and carbon–carbon coupling constants (in parentheses) in ^{13}C labelled compounds (5)—(8); δ_C (p.p.m.) (J_{CC} Hz)

Compound	Carbon number 1	2	3	4	5,9	6,8	7	10
(5a)	156.6	81.81 (119.3)	86.72 (18.4)	120.77 (2.0)	129.99 (~1.0)	133.73 [a]	131.73 [a]	
(5b)	153.16	81.75 (127.7)	87.85 (19.5)	120.93 (2.4)	129.94 (1.2)	134.37 [a]	132.10 [a]	54.07 (1.8)
(6a)	169.94	121.07 (72.0)	143.07 [a]	136.39 (~2.0)	130.61 [a]	129.00 [a]	129.81 [a]	
(6b)	166.44	119.18 (75.7)	143.20 [a]	134.66 (2.9)	129.65 [a]	127.92 [a]	128.95 [a]	51.22 (2.2)
(7a)	170.37	119.26 (72.6)	146.35 (1.4)	135.67 (6.6)	129.14 [a]	129.89 [a]	131.35 [a]	
(7b)	168.54	119.08 (76.5)	146.0 (2.2)	135.64 (7.4)	129.27 [a]	130.08 [a]	131.48 [a]	52.78 (2.2)
(8a)	176.73	36.59 (55.2)	31.85 (1.8)	141.59 (3.5)	129.37 [a,b]	129.21 [a,b]	127.11 [a]	
(8b)	172.74	35.23 (57.4)	30.54 (1.3)	140.25 [b] (3.6)	128.06 [a,b]	127.94 [a,b]	125.89 [a]	50.99 (2.2)

[a] Not observed, <0.6 Hz. [b] Assignments may be reversed.

^{13}C Spectra of acids were recorded in CD_3OD solutions and spectra of esters in $CDCl_3$ solutions.

TABLE 3

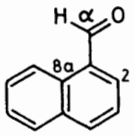
Chemical shifts and carbon–carbon coupling constants (in parentheses) in ^{13}C labelled compounds (9)—(12) δ_C (p.p.m.) (J_{CC}/Hz)

Compound	Carbon number 1	2	3	4	5	6	7	8	9	10
(9a) [c]	157.54	72.63 (123.0)	91.94 (19.3)	18.36 (~ 1.5)	28.34 [a,b]	27.38 [a,b]	31.15 [a]	22.36 [a]	13.62 [a]	
(9b)	154.12	72.74 (126.2)	89.68 (19.4)	18.45 [d]	28.32 [a,b]	27.35 [a,b]	31.02 [a]	22.28 [a]	13.75 [a]	52.28 (1.8)
(10a)	169.83	120.90 (70.8)	151.54 [a]	30.07 [a,b]	30.07 [a,b]	29.91 [a,b]	32.92 [a]	23.59 [a]	14.37 [a]	
(10b)	166.81	119.05 (73.6)	150.9 [a]	28.94 [a]	28.94 [a]	28.94 [a]	31.58 [a]	22.46 [a]	13.94 [a]	50.78 (2.7)
(11a)	170.10	122.47 (71.6)	151.2 (~0.7)	33.14 (6.4)	29.91 [a,b]	29.15 [a,b]	32.71 [a]	23.59 [a]	14.37 [a]	
(11b)	166.81	120.69 (74.2)	148.33 (0.9)	31.96 (7.2)	28.61 [a,b]	27.81 [a,b]	31.37 [a]	22.30 [a]	13.73 [a]	50.97 (2.7)
(12a)	177.76	34.92 (55.2)	25.90 (1.7)	30.25 (~2.9)	30.31 (~1.0)	30.25 [a]	32.92 [a]	23.63 [a]	14.5 [a]	
(12b)	173.74	33.72 (57.6)	24.65 (1.8)	28.87 (2.5)	28.86 [a]	28.87 [a]	31.5 [a]	22.33 [a]	13.64 [a]	50.83 (2.9)

Carbon-13 spectra of acids were recorded in CD_3OD solutions and of esters in $CDCl_3$ solution.

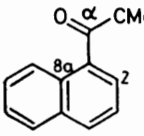
[a] Not observed, <0.6 Hz. [b] Assignments may be reversed. [c] The carbon-13 n.m.r. spectrum of nonynoic acid shows that C(2) is broader than the other signals ($W_{\frac{1}{2}}$ 3 Hz, 30%, $W_{\frac{1}{2}}$ 7 Hz, 2% v/v in [$^2H_4$]MeOH). The linewidths are not markedly dependent on temperature or magnetic field (22.6 and 90 MHz spectra were obtained). This rules out broadening due to dynamic processes or chemical-shift anisotropy. Ionisation of the carboxy-group gives a sharp line for C(2) and the spectrum of the methyl ester is normal. The possibility exists that aggregation of the hydrophobic acid may occur under the conditions employed leading to highly anisotropic motion. [d] Signal slightly broadened.

The *Z*-acid and ester may be expected to adopt more flexible *S-cis* configurations (18), the reduced coupling constant reflecting greater motional freedom and



$^2J_{C_\alpha C(2)}$ 5·8Hz
$^2J_{C_\alpha C(8a)}$ 2·5Hz

(13)



$^2J_{C_\alpha C(2)}$ 1·92 Hz
$^2J_{C_\alpha C(8a)}$ 1·77 Hz

(14)

contributions from non-planar conformations. In the *E*-series molecular models show that both planar conformations, *S-cis* (19a) and *S-trans* (19b) suffer severe non-bonded interactions between one of the oxygen atoms of the carboxy-group and the aromatic proton H(5). This will cause twisting about either C(1)–C(2) or C(3)–C(4) or both. In *cis*-β-methylcinnamic acid [10] the phenyl group is twisted 83° out of the plane of the double bond in the solid state. Additionally there may be some interaction between the ester methyl group and the *ortho*-protons of the *N*-benzoyl group causing torsion about C(1)–C(2) and C(2)–N so that the reduced coupling constants may reflect a lower degree of conjugation. It should be noted that the data indicate that for both the *Z*- and *E*-series the acid and ester adopt similar solution conformations.

In the αβ-unsaturated carboxylic acids the effect of geometry on the geminal coupling constants is observable but less marked. There has been little previous work in this area, the only report being on *cis*- and *trans*-cinnamic acids: [11] this is in close agreement with the values found here. If indeed lowered conjugation in the more hindered *cis*-series is responsible for the difference observed the lack of an additional bulky substituent should in these cases render the non-bonded interactions less severe than in the benzamido cinnamates. The geminal coupling constants in the acetylenic and saturated acids are unremarkable. The acetylenic acids give values similar to those determined by Marshall [12] and Jacobson [13] (+20.2 Hz for methyl propynoate) and the data for the saturated acids closely resemble those for butanoic and pentanoic acids.[14] The amino-acid derivatives (4a and b) had unmeasurably small geminal coupling constants in agreement with the data for phenylalanine where ^2JC(1)C(3) < 0.5 Hz.[15] Clearly either the effect of the nitrogen substituent is not analogous to that seen with the enamides or a change of sign is involved; ^2J is positive for acetylenes but negative in the saturated series.

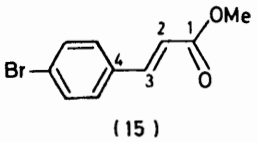
One-bond Coupling Constants.—The directly bonded coupling constants $^1J_{C_{(1)}C_{(2)}}$ follow the predicted order based on hybridisation.[16] In most cases the ester gives a value slightly larger than that for the corresponding acid; this has been previously observed [7,14] but a complete explanation is lacking.

TABLE 4

Carbon–proton coupling constants (Hz) in ^{13}C labelled compounds (5)—(12) ($CDCl_3$ solution; 90 MHz)

Compound	(5b)	(6a)	(6b)	(7a)	(7b)	(8a)	(8b)	(9a)	(9b)	(10a)	(10b)	(11a)	(11b)	(12a)	(12b)
$^2J_{C(1)H(2)}$		2.1	1.7	2.8	2.6	*a*	*a*			~1.7	1.5	3.5	3.2	~6.3	6.8
$^3J_{C(1)H(3)}$		14.0	14.4	7.0	6.8	*a*	*a*			14.6	14.6	6.7	6.8	*b*	*b*
$^4J_{C(1)H(4)}$								<1	~1.8	*a*	*a*		*a*		
$^3J_{C(1)OCH_3}$	4.2		3.9		3.9		3.8		4.4		3.9		3.75		3.8

[a] Not observed due to signal overlap. [b] Coupling not well resolved.



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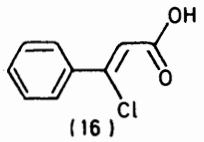

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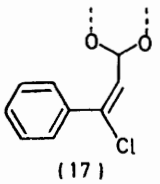
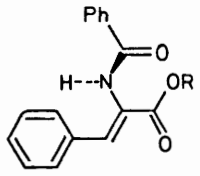


(17)

Vicinal Coupling Constants.—In vicinal coupling constants $^3J_{C(1)C(3)}$ show a very marked dependence both on hybridisation and geometry, particularly in the doubly-bonded species. Data on coupling across a triple bond are scarce but ^3J is small in methyl tetrolate (+1.84 Hz) [12] and dimethyl acetylenedicarboxylate (2.5 Hz).[17] From his study of labelled carboxylic acids [18] Marshall has proposed the use of a Karplus-type dependence for $^3J_{CC}$. The conformations of nonanoic and 3-phenylpropionic acids are unknown but their



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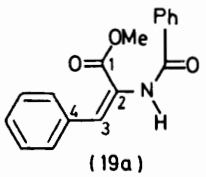
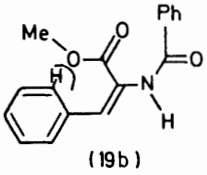


(19a)



(19b)

geometries might be expected to be fairly similar to that derived for butanoic acid by Marshall; the observed coupling constants are also similar. Vicinal coupling constants have been measured for *cis*- and *trans*-cinnamic acids [11] and for *cis*- and *trans*-but-2-enoic acids.[19] While neither these nor the data here reported can be fitted directly to the curve obtained by Marshall [18] it is clear that the same trends as seen in proton–proton and proton–carbon [4] coupling constants are followed. Both this and the $^3J_{CH}$ values of Table 4 will be of value in the determination of configuration about tri- and tetra-substituted double bonds where conventional methods based on inter-proton couplings cannot be employed. Increasing application of J spectroscopy [20] should make such coupling constants more accessible without the use of very high levels of isotopic labelling.

EXPERIMENTAL

All ^{1}H n.m.r. spectra were recorded at 90 MHz on a Perkin-Elmer R32 spectrometer in $CDCl_3$ solution. ^{13}C N.m.r. spectra were recorded at 22.63 MHz on a Brüker WH90 spectrometer. Chemical shifts are given in p.p.m. relative to internal or external $SiMe_4$.

[1,5-$^{13}C_2$]-(Z)-4-*Benzylidene*-2-*phenyloxazolin*-5(4H)-*one* (1a).—[1-^{13}C]Glycine was converted into hippuric acid (80%) using benzoyl chloride, m.p. 189—190° (lit.,[21] 191—192°). [1-^{13}C]Benzoic acid was prepared in 77% yield from phenylmagnesium bromide and barium carbonate (90.5 atom % ^{13}C) according to the published procedure.[22] A solution of the labelled acid (1.6 g, 13.1 mmol) and thionyl chloride (2.6 ml) in benzene (13 ml) was heated under reflux for 3 h, when benzene and unchanged thionyl chloride were removed by distillation.[23] It was then added to a slurry of triphenylphosphine (5.73 g, 26.2 mmol) and bis(triphenylphosphine)copper borohydride [24] in tetraglyme (4 ml; dried by distillation from sodium) and the mixture stirred at room temperature for 3.5 h. The apparatus was then connected to vacuum and [1-^{13}C]benzaldehyde (1.32 g) distilled out (40 °C; 0.15 mmHg). ^{1}H N.m.r. showed that this was contaminated with benzene and tetraglyme but was used without further purification. A suspension of [1-^{13}C]hippuric acid (0.46 g, 2.57 mmol), freshly fused sodium acetate (0.3 g, 4.55 mmol), and benzaldehyde (0.3 ml, 3 mmol) in acetic anhydride (5 ml) was heated at a temperature carefully maintained between 85 and 95 °C for 40 min. Ethanol (5 ml) and water (5 ml) were added cautiously to the warm solution causing the precipitation of a yellow solid. The slurry was poured into water (25 ml), the solid collected by filtration, washed with water and hexane, and dried. Crystallisation (CH_2Cl_2–EtOH) yielded oxazolinone (1a) (286 mg, 45%), m.p. 165—167° (lit.,[1] 167—170°).

1,3-$^{13}C_2$-*Labelled* (Z)-α-*Benzamidocinnamic Acid* (2a) *and* (Z)-*Methyl* α-*Benzamidocinnamate* (3a).—The labelled azlactone (1a) (200 mg, 0.8 mmol) was added to a mixture of methanol (4 ml) and sodium hydroxide solution (1M, 2 ml) and stirred until completely dissolved. Methanol was removed under reduced pressure and the solution extracted with ether (3 × 5 ml). The ether extract was dried (Na_2SO_4) and concentrated to give a solid. Crystallisation aqueous methanol) yielded ester (3a) (109 mg, 48%), m.p. 141—142° (lit.,[25] 142—143°). Concentrated hydrochloric acid was added to the aqueous layer until the pH value was 2. The precipitate was collected, washed with water, and dried *in vacuo* to give acid (2a) (52 mg, 24%), m.p. 225—230° (lit.,[1] 223—226°).

[1,5-$^{13}C_2$]-(E)-4-*Benzylidene*-2-*phenyloxazolin*-5(4H)-*one* (1b).—Gaseous hydrogen bromide was bubbled for 40 min through a slurry of (1a) (85 mg, 0.34 mmol) in glacial acetic acid (6 ml) with vigorous stirring. This was then poured into water (12 ml) and the cream precipitate collected, washed with water, and dried. The crude (1b) (80 mg, 94%), m.p. 138—140° (lit.,[1] 148—149°), contained *ca.* 5% (1a) (^{1}H n.m.r.) but was used without further purification.

[1,3-$^{13}C_2$]-(E)-*Methyl* α-*Benzamidocinnamate* (3b).—To (1b) (67 mg, 0.27 mmol) was added methanol (2 ml) and sodium hydroxide solution (1M, 0.7 ml) and the mixture stirred until dissolved (15 min). Methanol was removed under reduced pressure and the solution extracted with ether (2 × 3 ml). The ether extract was washed (water), dried (Na_2SO_4), and concentrated to a solid. Crystallisation (CH_2Cl_2–hexane) yielded ester (3b) (57 mg, 75%), m.p. 134—135° (lit.,[1] 134—135°).

[1,3-$^{13}C_2$]-(E)-α-*Benzamidocinnamic acid* (2b) was produced by hydrolysis of (3b) (NaOH; aqueous methanol; 20°; 3 h) (45 mg, 83%), m.p. 187—195° (lit.,[1] 199—208°).

1,3-$^{13}C_2$-*Labelled* N-*Benzoylphenylalanine* (4a) *and its Methyl Ester* (4b).—Ester (3a) (35 mg, 0.12 mmol) was hydrogenated in methanol using bicyclo[2,2,1]heptadiene-[bis(diphenylphosphino)propane]rhodium(I) tetrafluoroborate (6 mg, 8.6 μmol). Chromatography (SiO_2; eluting with ethyl acetate–hexane) yielded crude (4b) (34 mg, 97%) which was used without purification. Hydrolysis (NaOH; aqueous MeOH; 2 h; 20°) yielded (4a) (22 mg, 66%), m.p. 188—190° (lit.,[26] 187—188°).

[1-^{13}C]-3-*Phenylpropynoic Acid* (5a).—This was prepared by the carboxylation of phenylacetylene.[27] To a solution of phenylacetylene (1.2 ml, 11 mmol) in tetrahydrofuran (30 ml) was added n-butyl-lithium (1.7M in hexane; 11 mmol) and the solution cooled to −78 °C. Labelled $^{13}CO_2$ (90 atom % from concentrated sulphuric acid on $Ba^{13}CO_3$) was admitted over 30 min with vigorous stirring. The slurry was allowed to warm to room temperature over 30 min and then concentrated hydrochloric acid (10 ml), water (10 ml), and ether (30 ml) were added. The aqueous layer was discarded and the ethereal solution extracted with sodium hydroxide solution (1M; 3 × 20 ml). The aqueous extracts were acidified (concentrated hydrochloric acid), extracted with ether (3 × 20 ml), washed (water, saturated NaCl solution), dried (Na_2SO_4), and concentrated. Crystallisation (water) gave needles (650 mg, 45%), m.p. 136—139° (sublimes). The corresponding methyl ester was prepared in 80% yield (MeOH; toluene-*p*-sulphonic acid; 16 h; 70°) and purified by distillation (bath temperature 110° and 0.2 mmHg) (lit.,[28] 159—160° and 48 mmHg).

[1-^{13}C]-(Z)-*Cinnamic Acid* (6a).—This was prepared by hydrogenation of (5a) (Lindlar catalyst) in hexane (68%), m.p. 54—56° (from hexane) (lit.,[29] 58°). The methyl ester (6b) was prepared as above [(6a) (448 mg 3 mmol); toluene-*p*-sulphonic acid (50 mg); methanol; 70°; 10 h] and purified by distillation (bath temperature 120° and 0.15 mmHg) (lit.,[30] 70° and 0.2 mmHg) (297 mg, 70%).

[1-^{13}C]-(E)-*Methyl Cinnamate* (7b).—This was prepared by iodine-catalysed isomerisation [30] of (6b) (297 mg 1.2 mmol) (hexane; 70°; 6 days). Crystallisation (−30°; 2-methylbutane) gave a solid (250 mg, 84%), m.p. 26—28° (lit.,[31] 33—34°). [1-^{13}C]-(*E*)-Cinnamic acid (7a) was obtained by hydrolysis of (7b) (NaOH; aqueous methanol)

and purified by crystallisation from hot water (82%), m.p. 134—136°.

[1-^{13}C]-3-*Phenylpropionic Acid* (8a).—This was prepared by hydrogenation of (*E*)-cinnamic acid (5% Pd–C, EtOH) and purified by crystallisation from hexane (70%), m.p. 54—55° (lit.,[32] 48—50°) (a trace of cinnamic acid was detected by ^{1}H n.m.r.). Esterification (toluene-*p*-sulphonic acid; methanol; 70 °C; 2 h) yielded (8b) (67%) which was purified by distillation (bath temperature 90° and 0.1 mmHg) (lit.,[33] 238—239° and 756 mmHg).

[1-^{13}C]*Nonynoic Acid* (9a).—This was prepared in 73% yield as described for (5a) and purified by distillation (bath temperature 110° and 0.2 mmHg) (lit.,[34] 154—156° and 18 mmHg). Methylation as before yielded (9b) (80% distilled; bath temperature 100° and 0.1 mmHg) (lit.,[34] 85° and 2.3 mmHg).

[1-^{13}C]-(Z)-*Non-2-enoic Acid* (10a).—This was prepared by hydrogenation (Lindlar catalyst; hexane) of (9a) and purified by distillation (90%; bath temperature 115° and 0.2 mmHg) (lit.,[35] 149° and 22 mmHg). Methylation as before yielded (10b) (68%; distilled; bath temperature 95° and 0.1 mmHg) (lit.,[36] 111—113° and 25 mmHg).

[1-^{13}C]*Nonanoic Acid* (12a). This was prepared by carboxylation of octylmagnesium bromide in ether [37] and distilled (54%; bath temperature 120° and 0.15 mmHg) (lit.,[38] 255° and 760 mmHg). Methylation as before yielded (12b) (74%; distilled; bath temperature 90° and 0.3 mmHg) (lit.,[39] 213—214° and 756 mmHg).

[1-^{13}C]-(E)-*Methyl Non-2-enoate* (11b).—Attempts to isomerise (*Z*)-methyl non-2-enoate with iodine,[30] sodium hydroxide, benzenethiol,[40] and trifluoroacetic acid proved futile. To a solution of di-isopropylamine (0.57 ml, 3.7 mmol) in dry tetrahydrofuran (10 ml) was added n-butyllithium (1.7M in hexane; 3.7 mmol) at 0°. Methyl nonanoate (532 mg, 3.1 mmol) was added and the solution cooled to −78°. Benzeneselenenyl chloride [41] (668 mg, 3.5 mmol) was added and the solution allowed to warm to room temperature and treated with water (10 ml). This was extracted with ether (3 × 10 ml) and the ether layers washed, dried (Na_2SO_4), and concentrated to give a yellow semi-solid, the α-phenylselenoester, which was used without further purification. This was added to a mixture of dichloromethane (10 ml), water (1 ml), and hydrogen peroxide (30%, 0.8 g) at 0° and stirred for 1 h as it warmed to room temperature. The mixture was extracted with dichloromethane (3 × 10 ml) and the extracts washed, dried ($MgSO_4$), and concentrated. Distillation (bath temperature 100° and 0.1 mmHg) (lit.,[42] 111—120° and 19 mmHg) yielded (11b) (380 mg, 64%) uncontaminated (^{1}H n.m.r.) by the *Z*-ester. Hydrolysis (NaOH; aqueous methanol) yielded (*E*)-non-2-enoic acid (11a) which was purified by distillation (bath temperature 105° and 0.2 mmHg) (lit.,[35] 173° and 20 mmHg). The ^{13}C labelled acid and ester were prepared analogously in similar yield.

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