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Research Article

The first synthesis of all possible isotopically labelled [D, ^{13}C] methyl group combinations of 2,2-dimethyl tetralone

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Summary

A series of multi-labelled [D, ^{13}C] 2,2-dimethyl tetralones were efficiently synthesized using a simple and diverse deprotonation–methylation strategy. All possible ten isotopic combinations were synthesized. The levels of [D, ^{13}C] isotopic incorporation were quantitative and the synthetic yields were high. Copyright © 2002 John Wiley & Sons, Ltd.

Key Words: deuterium; enolate; methyl iodide; lithium amide bases; isotopic labels; tetralone

Introduction

The continuing development of new methods and the extension of existing methodology for selective incorporation of non-radioactive isotopic labels within organic molecules is an important area.[1] The incorporation of a deuterium atom or a carbon-13-labelled substituent has generally relied on simple carbon–hydrogen bond substitution reactions.[2,†,‡,§] These exchange processes occur more readily at

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† For D incorporation see ref. 2(a).
‡ For ^{13}C incorporation see ref. 2(b)
§ For CD_3 incorporation see ref. 2(c).

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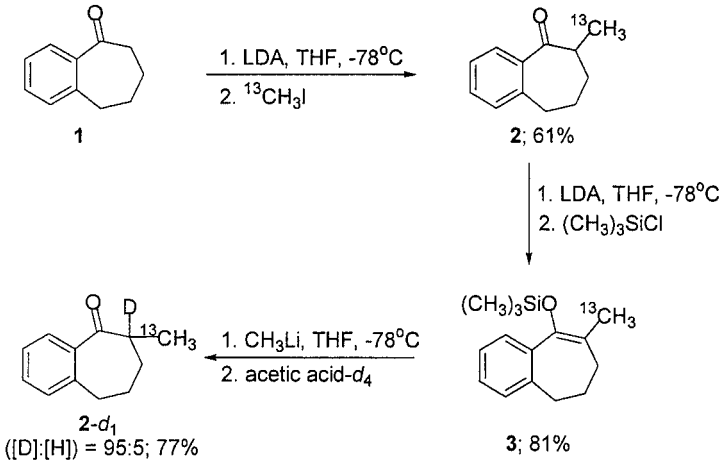
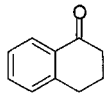
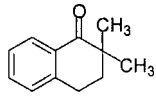
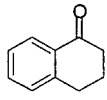
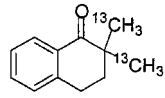
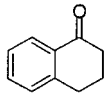
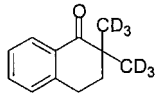
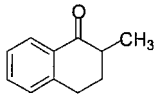
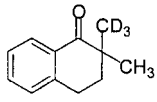
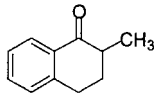
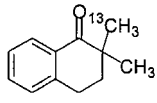
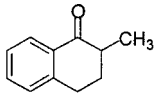
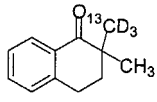
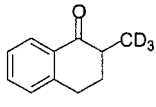
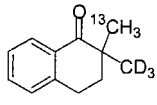
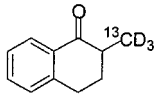
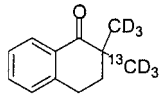
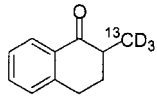
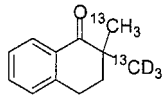
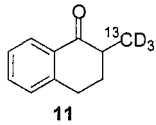
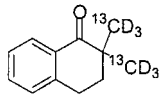


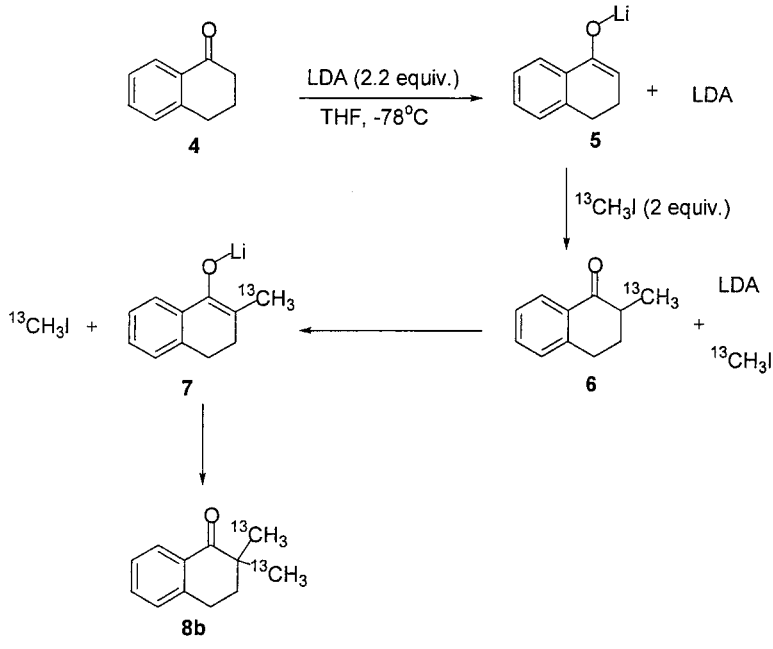
Scheme 1. Synthesis of 2-methyl-[^{13}C]-suberone 2-d_1.

relatively acidic positions,[3] and many of these reactions have been performed under thermodynamic control[4] to improve the overall level of isotopic incorporation. However, we have tried to address this balance by synthesizing a series of multi-labelled [D, ^{13}C] 2-deuterio-2-methyl aromatic ketones like **2**-d_1, under kinetic control using 'base-free' enolate[5] methodology (Scheme 1, Table 1).[6] For example, treatment of the silyl enol ether **3** with a solution of CH_3Li (in hexane) and subsequent addition of acetic acid-d_4 (3 equivalents) gave the deuterium-labelled 2-deuterio-2-methyl-[^{13}C] benzosuberone **2**-d_1 in good yield (77%) with near perfect incorporation ([D] : [H] = 95 : 5).[6] The required silyl enol ether **3** was efficiently synthesized by direct deprotonation of the parent 2-methyl-[^{13}C] benzosuberone **2** (formed by selective methylation of benzosuberone **1**)[6] with LDA and addition of $(CH_3)_3SiCl$.[5]

We now extend this methodology by reporting the first synthesis of all ten isotopically labelled [D,^{13}C] methyl group combinations of a simple 2,2-dimethyl aromatic ketone. We comment on the similarity and differences between these isotopic substitution patterns by ^{1}H and ^{13}C NMR spectroscopy. We originally chose the tetralone framework to test this methodology due to its UV activity, non-volatile nature and predictable enolate chemistry.[7] We initially concentrated on the synthesis of the symmetrically methyl (CH_3), methyl-[^{13}C] ($^{13}CH_3$), 2-trideuteriomethyl (CD_3) and 2-trideuteriomethyl-[^{13}C] ($^{13}CD_3$) labelled tetralones **8a**,[10a] **8b**, **8c** and **8j** using an in situ double

Table 1. The synthesis of multi-labelled 2,2-dimethyltetralones 8a–j

Entry	Starting material	Methyl ketone
1	 **4**	 **8a**; 82%
2	 **4**	 **8b**; 63%
3	 **4**	 **8c**; 78%
4	 **9**	 **8d**; 61%
5	 **9**	 **8e**; 71%
6	 **9**	 **8f**; 73%
7	 **10**	 **8g**; 72%
8	 **11**	 **8h**; 76%
9	 **11**	 **8i**; 73%
10	 **11**	 **8j**; 71%



Scheme 2. Synthesis of 2,2-dimethyl-[^{13}C]-tetralone 8b.

deprotonation and methylation strategy (Scheme 2). Addition of tetralone **4** (1 equivalent) to a stirred solution of lithium diisopropylamide (2.2 equivalents) at -78°C, followed by the addition of the appropriately isotopically labelled methyl iodide [CH_3I, CD_3I, $^{13}CH_3I$ and $^{13}CD_3I$ (2.2 equivalents)] gave the required 2,2-dimethyl tetralones **8a**,[10a] **8b**, **8c** and **8j** in good yield. These reactions must proceed via the corresponding 2-methyl labelled tetralone (e.g., **6**) by methylation of enolate **5** – subsequent deprotonation with the remaining equivalent of lithium diisopropylamide and regioselective *C*-methylation of the resulting enolate **7** leads to the required 2,2-dimethyl tetralone **8b**. This strategy is ideal since quantitative isotopic incorporation only occurs via simple carbon–carbon bond formation.

These symmetrical derivatives **8a**,[10a] **8b**, **8c** and **8j** were easily characterized by ^{1}H and ^{13}C NMR spectroscopy. In the ^{1}H NMR spectra, the $CH_2C=O$ signal was replaced with either a double doublet ($^1J_{C,H} = 127.5$ and $^3J_{C,H} = 4.6$ Hz) at δ1.2 ppm due to a combination of ^{13}C couplings resulting from the $^{13}CH_3$ label or disappeared due to the presence of deuterium within the labelled methyl substituents (CD_3 and $^{13}CD_3$). In the ^{13}C NMR spectra, the presence of a deuterium atom on a

particular adjacent carbon atom caused the signal intensity to be lowered due to a combination of ^{13}C–D coupling and larger T_1 relaxation time associated with this substituent.[8] By comparison between these derivatives, we have noticed that the relative signal intensity for each isotopic methyl substituent was in the following order; $^{13}CH_3 > {}^{13}CD_3 > CH_3 > CD_3$. The additional presence of a carbon-13 label is particularly interesting for both $^{13}CH_3$ and $^{13}CD_3$ containing derivatives **8b** and **8j** since this gives rise to a triplet ($^2J_{C,C}$= 35 Hz at approximately 41 ppm) in the ^{13}C NMR spectra for the C(2) position. The additional presence of deuterium within the $^{13}CD_3$ group significantly lowers the signal intensity giving rise to a septet [1:3:6:7:6:3:1] with characteristic ($^1J_{C,D}$) ^{13}C–D coupling of 19 Hz.[8,9]

The unsymmetrically 2-trideuteriomethyl (CD_3), 2-trideuteriomethyl-[^{13}C] ($^{13}CD_3$) and methyl-[^{13}C] ($^{13}CH_3$) labelled tetralones **8d–i** were synthesised in a similar fashion by deprotonation and methylation of various isotopically labelled 2-methyl tetralones **9**,[10a] **10**[6] and **11**.[6] These unsymmetrically labelled derivatives are evidently chiral due to the presence of the two isotopically labelled methyl substituents at the C(2) position. This newly introduced stereogenic centre understandably has very little effect on the visible diastereotopicity of the adjacent CH_2 positions (by ^{1}H NMR spectrscopy), all appear to have classical first order couplings. For those tetralones **8e–i** which contained a single ^{13}C label, the C(3)H_2 protons in the ^{1}H NMR spectra appear as a triple doublet ($^3J_{H,H}$= 6.4 Hz and $^3J_{C,H}$= 3.7 Hz) at around δ1.9 ppm.

The associated methyl signal in the ^{1}H NMR spectra for these unsymmetrically labelled derivatives **8e–i** were particularly interesting when at least one ^{13}C label was present; for 2-dimethyl-[^{13}C]-2-methyltetralone **8e**, the $^{13}CH_3$ group gave rise to a doublet (at δ 1.23 ppm) with a characteristically large geminal coupling ($^1J_{C,H}$= 127.9 Hz), whereas, the remaining unlabelled CH_3 group gave rise to a doublet (at δ 1.21 ppm) with a much smaller coupling ($^3J_{C,H}$= 4.8 Hz). For those derivatives **8i–j** which contained two different ^{13}C labelled methyl groups, such as in 2-trideuteriomethyl-[^{13}C]-2-methyl-[^{13}C]-tetralone **8i**, the corresponding C(3)H_2 protons appeared as a triple triplet at 1.9 ppm with vicinal couplings of 6.4 Hz ($^3J_{H,H}$) and 3.7 Hz ($^3J_{C,H}$).

In conclusion, we have reported the first synthetic route for the synthesis of all possible combinations of symmetrically and unsymmetrically labelled [D, ^{13}C] 2,2-dimethyl tetralones. The level of isotopic incorporation was quantitative since it relied on simple carbon–carbon

bond formation. Using four different isotopic methyl substituents (CH_3, CD_3, $^{13}CH_3$ and $^{13}CD_3$), a maximium of ten related isotopic derivatives were synthesized. Interestingly, we have also found for such derivatives, the size of the ^1H, ^{13}C couplings were uniform [$^1J_{C,H}$= 127 Hz, $^2J_{C,H}$= 6.7 Hz, $^3J_{C,H}$= 4.8 Hz (exocyclic CH) and $^3J_{C,H}$= 3.7 Hz (endocyclic CH)]. The relative signal intensity in the ^{13}C NMR for these four related isotopic methyl substituents were also found to be in the order: $^{13}CH_3 > {}^{13}CD_3 > CH_3 > CD_3$.

Reports into the synthesis of isotopically labelled 2-methyl carbonyl derivatives using an enolate strategy are well known.[11] By comparison, the synthesis of multi-labelled 2,2-dimethyl carbonyl derivatives are much rarer.[12] Nevertheless, these differentially labelled compounds have found use as mechanistic probes in chemical[13] and NMR experiments.[14]

Experimental

Proton and carbon NMR spectra were recorded on a JEOL EX 270 and Bruker AM 250, AMX 400 and AM 600 fourier transform spectrometer (using an internal deuterium lock). Chemical shifts are quoted in parts per million downfield from tetramethylsilane. Carbon NMR spectra were recorded with broad proton decoupling. Infrared spectra were recorded on a Shimadzu 8300 FTIR machine and mass spectra were recorded on a Kratos 50MSTC machine using a DS503 data system for high-resolution analysis.

2,2-Dimethyltetralone **8a**[10b]. tetralone **4** (0.2 g, 1.37 mmol) was slowly added to a solution of LDA (1.8 ml, 1.5 M in THF, 2.74 mmol) in THF (10 ml) at −78°C and stirred for 30 min. Methyl iodide (0.39 g, 0.17 ml, 2.74 mmol) was added dropwise and the resulting solution was stirred for 12 h and allowed to warm to room temperature. A solution of NH_4Cl (saturated, 10 ml) was added and the mixture was extracted with ether (3 × 50 ml). The combined organic layers were dried ($MgSO_4$) and evaporated under reduced pressure. The residue was purified by flash column chromatography on silica gel eluting with light petroleum (b.p. 40–60°C)–ether (19:1) to give 2,2-dimethyltetralone **8a** (0.19 g, 63%) as an oil; R_F [light petroleum (40–60°C):ether (9:1)] 0.6; ν_{max} (film)/cm^{-1} 1680 (CO); δ_H (270 MHz, $CDCl_3$) 8.05 (1 H, d, $^3J_{H,H}$ = 7.5, CH; Ar), 7.45 (1 H, t, $^3J_{H,H}$ = 7.5, CH; Ar), 7.29 (1 H, t, $^3J_{H,H}$ = 7.5, CH; Ar), 7.20 (1 H, d, $^3J_{H,H}$ = 7.5, CH; Ar), 2.98 (2 H, t, $^3J_{H,H}$ = 6.5, CH_2), 1.99 (2 H, t, $^3J_{H,H}$ = 6.5, CH_2) and 1.20 (6 H, s, 2 × CH_3); δ_C (62.5 MHz,

$CDCl_3$) 203.2, 143.8, 133.4, 131.8, 129.1, 128.4, 127.0, 42.0, 37.1 26.1 and 24.8 ($2 \times CH_3$) (Found MH^+, 175.1120. $C_{12}H_{15}O$ requires MH, 175.1123).

2,2-Dimethyl-[^{13}C]-tetralone **8b**. In the same way as 2,2-dimethyltetralone **8a**, tetralone **4** (0.2 g, 1.37 mmol), LDA (1.8 ml, 1.5 M in THF, 2.74 mmol) and methyl iodide-d_3 (0.39 g, 0.17 ml 2.74 mmol) gave, after column chromatography on silica gel eluting with light petroleum ether–ether (19:1) 2,2-*dimethyl-[^{13}C]-tetralone* **8b** (0.15 g, 63%) as an oil; R_F [light petroleum (40–60°C):ether (9:1)] 0.6; ν_{max} (film)/cm^{-1} 1680 (CO); δ_H (270 MHz, $CDCl_3$) 8.03 (1 H, d, $^3J_{H,H} = 7.5$, CH; Ar), 7.44 (1 H, t, $^3J_{H,H} = 7.5$, CH; Ar), 7.28 (1 H, t, $^3J_{H,H} = 7.5$, CH; Ar), 7.20 (1 H, d, $^3J_{H,H} = 7.5$, CH; Ar), 2.97 (2 H, t, $^3J_{H,H} = 6.5$, CH_2), 1.97 (2 H, tt, $^3J_{H,H} = 6.5$ and $^3J_{C,H} = 3.5$, CH_2) and 1.20 (6 H, dd, $^1J_{C,H} = 127.1$ and $^3J_{C,H} = 4.6, 2\times{}^{13}CH_3$); δ_C (62.5 MHz, $CDCl_3$) 202.9, 143.2, 132.8, 131.8, 128.5, 127.8, 126.4, 41.4 (1 C, triplet [1:1:1], $^2J_{C,C} = 35$, $C^{13}CH_3$), 36.6 25.7 and 23.5 ($2 \times {}^{13}CH_3$) (Found MH^+, 177.1197. $C_{10}^{13}C_2H_{15}O$ requires MH, 177.1190).

2,2-Di-Trideuteriomethyltetralone **8c**-d_3. The synthesis of this derivative has been reported elsewhere.[8]

2-Trideuteriomethyl-2-methyltetralone **8d**-d_3. In the same way as 2,2-dimethyltetralone **8a**, 2-methyltetralone **9**[10a] (0.3 g, 1.9 mmol), LDA (1.3 ml, 1.5 M in THF, 1.9 mmol) and methyl iodide–d_3 (0.27 g, 0.12 ml 1.9 mmol) gave, after column chromatography on silica gel eluting with light petroleum ether–ether (19:1) 2-*trideuteriomethyl*-2-*methyltetralone* **8d**-d_3 (0.21 g, 61%) as an oil; R_F [light petroleum (40–60°C):ether (9:1)] 0.6; ν_{max} (film)/cm^{-1} 2080 (CD) and 1682 (CO); δ_H (250 MHz, $CDCl_3$) 8.03 (1 H, d, $^3J_{H,H} = 7.6$, CH; Ar), 7.45 (1 H, t, $^3J_{H,H} = 7.5$, CH; Ar), 7.28 (1 H, t, $^3J_{H,H} = 7.5$, CH; Ar), 7.20 (1 H, d, $^3J_{H,H} = 7.6$, CH; Ar), 2.96 (2 H, t, $^3J_{H,H} = 6.4$, CH_2), 1.95 (2 H, t, $^3J_{H,H} = 6.4$, CH_2) and 1.20 (3 H, s, CH_3); δ_C (62.5 MHz, $CDCl_3$) 202.9, 143.3, 132.9, 131.4, 128.6, 127.9, 126.5, 41.4, 36.5, 25.7, 24.2 (CH_3) and 23.3 (1 C, quintet [3:6:7:6:3], $^1J_{C-D} = 19.0$, CD_3) (Found MH^+, 178.1306. $C_{12}H_{12}D_3O$ requires MH, 178.1331).

2-Methyl-[^{13}C]-methyltetralone **8e**. In the same way as 2,2-dimethyltetralone **8a**, 2-methyltetralone **9**[10a] (0.2 g, 1.3 mmol), LDA (0.6 ml, 1.5 M in THF, 1.3 mmol) and methyl-[^{13}C]-iodide (0.18 g, 0.85 µl, 1.3 mmol) gave, after column chromatography on silica gel eluting with light petroleum ether–ether (19:1) 2-*methyl-[^{13}C]-methyltetralone* **8e** (0.15 g, 71%) as an oil; R_F [light petroleum (40–60°C):ether (9:1)] 0.6; ν_{max} (film)/cm^{-1} 1690 (CO); δ_H (62.5 MHz, $CDCl_3$) 8.05 (1 H, d,

$^3J_{H,H}$ = 7.6, CH; Ar), 7.46 (1 H, t, $^3J_{H,H}$ = 7.5, CH; Ar), 7.32 (1 H, d, $^3J_{H,H}$ = 7.5, CH; Ar), 7.23 (1 H, d, $^3J_{H,H}$ = 7.6, CH; Ar), 2.99 (2 H, t, $^3J_{H,H}$ = 6.4, CH_2), 1.99 (2 H, td, $^3J_{H,H}$ = 6.4 and $^3J_{C,H}$ = 3.8, CH_2) 1.23 (3 H, d, $^1J_{C,H}$ 127.9, $^{13}CH_3$) and 1.21 (3 H, d, $^3J_{C,H}$ = 4.8, CH_3); δ_C (62.5 MHz, $CDCl_3$) 202.9, 143.4, 132.9, 131.5, 128.7, 127.9, 126.6, 41.4, 36.6, 25.7 and 24.3 ($^{13}CH_3$ and CH_3) (Found MH^+, 175.1072. $C_{11}^{13}CH_{15}O$ requires MH, 175.1078).

2-Trideuteriomethyl-[^{13}C]-2-methyltetralone **8f**-d_3. In the same way as 2,2-dimethyltetralone **8a**, 2-trideuteriomethyltetralone **9**[6] (0.10 g, 0.62 mmol), LDA (0.42 ml, 1.5 M in THF, 0.62 mmol) and methyl-[^{13}C]-iodide-d_3 (90 mg, 38 µl, 0.62 mmol) gave, after column chromatography on silica gel eluting with light petroleum ether–ether (19:1) 2-*trideuteriomethyl-[^{13}C]-2-methyltetralone* **8f**-d_3 (81 mg, 73%) as an oil; R_F [light petroleum (40–60°C):ether (9:1)] 0.6; ν_{max} (film)/cm^{-1} 2091 (CD) and 1682 (CO); δ_H (250 MHz, $CDCl_3$) 8.02 (1 H, d, $^3J_{H,H}$ = 7.6, CH, Ar), 7.42 (1 H, t, $^3J_{H,H}$ = 7.6, CH; Ar), 7.31 (1 H, t, $^3J_{H,H}$ = 7.6, CH; Ar), 7.21 (1 H, d, $^3J_{H,H}$ = 7.6, CH; Ar), 3.0 (2 H, t, $^3J_{H,H}$ = 6.3, CH_2), 1.99 (2 H, td, $^3J_{H,H}$ = 6.5 and $^3J_{C,H}$ = 3.7, CH_2) and 1.25 (3 H, d, $^3J_{C,H}$ = 4.7, CH_3); δ_C (100.6 MHz, $CDCl_3$) 202.9, 143.3, 132.9, 131.4, 128.6, 127.9, 126.5, 41.2 (1 C, d [1:1], $^1J_{C,H}$ = 35.0, $C^{13}C$), 36.5, 25.6, 23.7 (1 C, quintet [3:6:7:6:3], $^1J_{C,D}$ = 20.0, $^{13}CD_3$) and 23.6 (CH_3) (Found MH^+, 179.1340. $C_{11}^{13}CH_{12}D_3O$ requires MH, 179.1345).

2-Trideuteriomethyl-2-methyl-[^{13}C]-tetralone **8g**-d_3. In the same way as 2,2-dimethyltetralone **8a**, 2-trideuteriomethyltetralone **10**[6] (62 mg, 0.38 mmol), LDA (0.3 ml, 1.5 M in THF, 0.38 mmol) and methyl iodide-d_3 (55 mg, 24 µl, 0.38 mmol) gave, after column chromatography on silica gel eluting with light petroleum ether–ether (19:1) 2-*trideuteriomethyl*-2-*methyl-[^{13}C]-tetralone* **8g**-d_3 (49 mg, 72%) as an oil; R_F [light petroleum (40–60°C):ether (9:1)] 0.6; ν_{max} (film)/cm^{-1} 2139 (CD) and 1682 (CO); δ_H (250 MHz, $CDCl_3$) 8.04 (1 H, d, $^3J_{H,H}$ = 7.6, CH; Ar), 7.45 (1 H, t, $^3J_{H,H}$ = 7.6, CH; Ar), 7.32 (1 H, t, $^3J_{H,H}$ = 7.5, CH; Ar), 7.20 (1 H, d, $^3J_{H,H}$ = 7.5, CH; Ar), 2.88 (2 H, t, $^3J_{H,H}$ = 6.3, CH_2) and 1.97 (2 H, td, $^3J_{H,H}$ = 6.4 and $^3J_{C,H}$ = 3.9, CH_2) and 1.22 (3 H, d, $^1J_{C,H}$ = 127.3, $^{13}CH_3$); δ_C (100.6 MHz, $CDCl_3$) 202.9, 143.3, 132.9, 131.4, 128.6, 127.9, 126.5, 41.3 (1 C, d, $^1J_{C,C}$ = 34.9, $C^{13}CH_3$), 36.5, 26.1 and 24.2 ($^{13}CH_3$) (Found MH^+, 179.1354. $C_{11}^{13}CH_{12}D_3O$ requires MH, 179.1345). The absence of the septet [1:3:6:7:6:3:1] around 25 ppm for the CD_3 signal in the ^{13}C NMR spectrum is common due to a long T_1 relaxation time associated with this substituent.[8]

2-Trideuteriomethyl-[^{13}C]-2-trideuteriomethyl tetralone **8h**-d_6. In the same way as 2,2-dimethyltetralone **8a**, 2-trideuteriomethyl-[^{13}C]-tetralone **11**[6] (0.1 g, 0.61 mmol), LDA (0.4 ml, 1.5 M in THF, 0.61 mmol) and methyl iodide-d_3 (88 mg, 38 µl, 0.62 mmol) gave, after column chromatography on silica gel eluting with light petroleum ether–ether (19:1) the *2-trideuteriomethyl-[^{13}C]-2-trideuteriomethyl tetralone* **8h**-d_6 (86 mg, 76%) as an oil; R_F [light petroleum (40–60°C):ether (9:1)] 0.6; ν_{max} (film)/cm^{-1} 2074 (CD) and 1656 (CO); δ_H (250 MHz, $CDCl_3$) 8.04 (1 H, d, $^3J_{H,H} = 7.6$, CH; Ar), 7.40 (1 H, t, $^3J_{H,H} = 7.6$, CH; Ar), 7.25 (1 H, d, $^3J_{H,H} = 7.5$, CH; Ar), 7.21 (1 H, d, $^3J_{H,H} = 7.5$, CH; Ar), 2.97 (2 H, t, $^3J_{H,H} = 6.4$, CH_2) and 1.95 (2 H, td, $^3J_{H,H} = 6.4$ and $^3J_{C,H} = 3.7$, CH_2); δ_C (100.6 MHz, $CDCl_3$) 202.9, 143.3, 132.9, 131.4, 128.6, 127.9, 126.5, 41.2 (1 C, d [1:1], $^1J_{C,C} = 34.6$, C^{13}C), 36.4, 25.6 and 23.6 (1 C, septet [1:3:6:7:6:3:1], $^1J_{C,D} = 20.2$, $^{13}CD_3$) (Found MH^+, 182.1460. $C^{13}_{11}CH_9D_6O$ requires MH, 182.1462). The absence of the septet [1:3:6:7:3:1] (around 25 ppm) for the CD_3 signal in the ^{13}C NMR spectrum is common due to a long T_1 relaxation time associated with this substituent.[8]

2-Trideuteriomethyl-[^{13}C]-2-methyl-[^{13}C]-tetralone **8i**-d_3. In the same way as 2,2-dimethyltetralone **8a**, 2-trideuteriomethyl-[^{13}C]-tetralone **11**[6] (0.10 g, 0.62 mmol), LDA (0.4 ml, 1.5 M in THF, 0.62 mmol) and methyl-[^{13}C]-iodide-d_3 (88 mg, 37 µl, 0.62 mmol) gave, after column chromatography on silica gel eluting with light petroleum ether–ether (19:1) the *2-trideuteriomethyl-[^{13}C]-methyl-[^{13}C]-tetralone* **8i**-d_3 (82 mg, 73%) as an oil; R_F [light petroleum (40–60°C):ether (9:1)] 0.6; ν_{max} (film)/cm^{-1} 2065 (CD) and 1680 (CO); δ_H (250 MHz, $CDCl_3$) 8.03 (1 H, d, $^3J_{H,H} = 7.6$, CH; Ar), 7.44 (1 H, t, $^3J_{H,H} = 7.6$, CH; Ar), 7.30 (1 H, d, $^3J_{H,H} = 7.5$, CH; Ar), 7.21 (1 H, d, $^3J_{H,H} = 7.5$, CH; Ar), 2.88 (2 H, t, $^3J_{H,H} = 6.3$, CH_2) and 1.99 (2 H, tt, $^3J_{H,H} = 6.3$ and $^3J_{C,H} = 3.7$, CH_2) and 1.20 (3 H, dd, $^1J_{C,H} = 127.3$ and $^3J_{C,H} = 4.8$, CH_3); δ_C (100.6 MHz, $CDCl_3$) 202.9, 143.4, 132.9, 131.4, 128.6, 127.9, 126.5, 41.4 (1 C, t, $^1J_{C,C} = 35.6$, C^{13}C), 36.5, 25.6 ($^{13}CH_3$) and 23.6 (1 C, septet [1:3:6:7:6:3:1], $^1J_{C,D} = 19.2$) (Found MH^+, 180.1369. C_{10} $^{13}C_2H_{12}D_6O$ requires MH, 180.1378).

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