Supplementary Material (ESI) for Green Chemistry


**Supporting Information**

# Rhodium-Catalysed isomerisation of allylic alcohols in water at ambient temperature

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## General

All reactions were carried out under a nitrogen atmosphere. Deionised water was degassed by bubbling through a stream of nitrogen for 30 min prior to use. Reagents were of analytical grade, and used as obtained from commercial suppliers without further purification. Compounds **4**[1], **5a-e, h, j, o**[2] and [$D_1$]**1a**[3] were prepared by methods previously described in the literature. Compounds **5f-g**, **l-n** were used as obtained from supplier. Flash chromatography was carried out on 60 Å (35-70 μm) silica gel. $^1$H and $^{13}$C NMR spectra were recorded at 400 or 500 MHz and at 100 or 125 MHz, respectively, on a Bruker Advance spectrometer. Chemical shifts ($\delta$) are reported in ppm, using the residual solvent peaks in $CDCl_3$ ($\delta_H$ 7.26 and $\delta_C$ 77.00) as internal standard. Coupling constants ($J$) are given in Hz. High resolution mass spectra (HRMS) were recorded on Bruker microTOF ESI-TOF mass spectrometer.

## General procedure for the isomerisation of allylic alcohols in water

To the allylic alcohol (0.4 mmol or 0.8 mmol) was added an 8 mM solution of $[Rh(COD)(MeCN)_2]BF_4$ (1 or 2 mL, 0.008 mmol or 0.016 mol, 2 mol %) and PTA (0.016 mmol or 0.032 mmol, 4 mol%) in water. The reaction was vigorously stirred (maximum speed of magnetic stirrer 1200 min$^{-1}$, according to supplier) in a closed tube at room temperature (or the temperature indicated) for the appropriate time (see table 2). The tube was opened, and the reaction mixture immediately extracted with $Et_2O$ (3x0.5 mL) and analysed by TLC and $^1$H-NMR. If heated, the reaction mixture was poured onto ice prior to extraction.

The NMR data of compounds **6a-g, i-n** were identical to those of the commercially available compounds.

**6h:** NMR ($CDCl_3$, 500 MHz): $\delta$ 7.57-7.54 (3H, m), 7.39-7.38 (3H, m), 6.74 (1H, d, $J$ = 16.2 Hz), 2.70 (2H, q, $J$ = 7.3 Hz), 1.17 (3H, t, $J$ = 7.3 Hz).

**[$D_1$]5:** $^1$H NMR ($CDCl_3$, 500 MHz): $\delta$ 7.98-7.95 (2H, m), 7.57-7.52 (1H, m), 7.47-7.43 (2H, m), 2.99 (2H, tt, $^3J_{HH}$ = 7.2 Hz, $^3J_{HD}$ = 1.0 Hz), 1.21 (2H, tt, $^3J_{HH}$ = 7.2 Hz, $^2J_{HD}$ = 2.0 Hz); $^{13}$C NMR ($CDCl_3$, 125 MHz): $\delta$ 200.8, 136.9, 132.8, 128.5, 127.9, 31.7, 7.9 (1C, t, $^1J_{C,D}$ = 19,6 Hz); HRMS-ESI: *m/z* 158.0684 ([M+Na]$^+$, $C_9H_9DONa$ calcd. 158.0687). Deuterium content 96 % (determined by $^1$H-NMR).

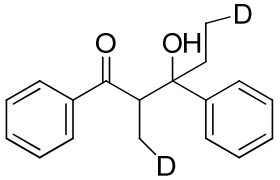
The NMR data were identical to those previously reported for this compound.[4]

The crossover experiment shown in Scheme 4 of this paper was analyzed by $^1$H and $^{13}$C NMR spectroscopy (see spectra bellow), as well as by mass spectroscopy. The mass spectroscopy analysis was performed at the RIAIDT, Unidade de Espectrometria de Masas, Edificio CACTUS, Universidad de Santiago de Compostela. The mixture of ketones obtained, **6o**-$d_x$ and **6a**-$d_x$, was separated from catalyst residues by $SiO_2$ column chromatography before being analyzed. The sample containing **6o**-$d_x$ and **6a**-$d_x$ (<10 mg), was first dissolved in $CH_2Cl_2$ (50 µL). An aliquot of this solution, 10 µL, was diluted to a final volume of 1000 µL using a MeOH / $H_2O$ mixture containing 0.1% of formic acid. This sample was injected into the HPLC using a Zorbax Eclipse XDB C18, 2.1x150 mm, 5 µ column (Agilent) and Zorbax, 2.1x12.5 mm, 5 µ (Agilent) precolumn. The run time was 40 min, using a flow of 0.2 mL / min. The column oven temperature was set to 25 ºC. A gradient of solvents was used as follows:

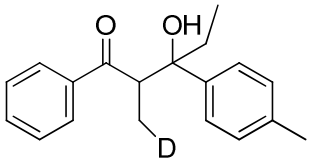
-Solvents: **A**: Water-Formic Acid 0.1%, and **B**:MeOH-Formic Acid 0.1%

| -Gradient: | t/min | 0 | 25 | 30 | 35 | 36 |
|---|---|---|---|---|---|---|
| | % B | 20 | 100 | 100 | 100 | 20 |

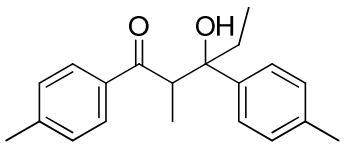
The HPLC chromatogram showed three main peaks (P1, P2, and P3), with an intensity of *ca.* 1:2:1 and retention times of 27.5, 28.6 and 29.4 min respectively. Analysis of each of these peaks by low resolution mass spectroscopy using ESI-TOF indicated that P1 corresponded to $C_{18}H_{18}D_2Na_1O_2$ [293.15 (100)], P2 to $C_{19}H_{21}DNa_1O_2$ [306.16 (100)], and P3 to $C_{20}H_{24}Na_1O_2$ [319.17 (100)]. These molecular formulae correspond to the aldol products formed when the sample containing a mixture of ketones **6o**-$d_x$ and **6a**-$d_x$ was treated with the acidic conditions used for separation in the HPLC. The intensity of the three peaks in the HPLC reflects the formation of a statistical mixture. The structure of the aldol products is shown bellow:



P1



P2



P3

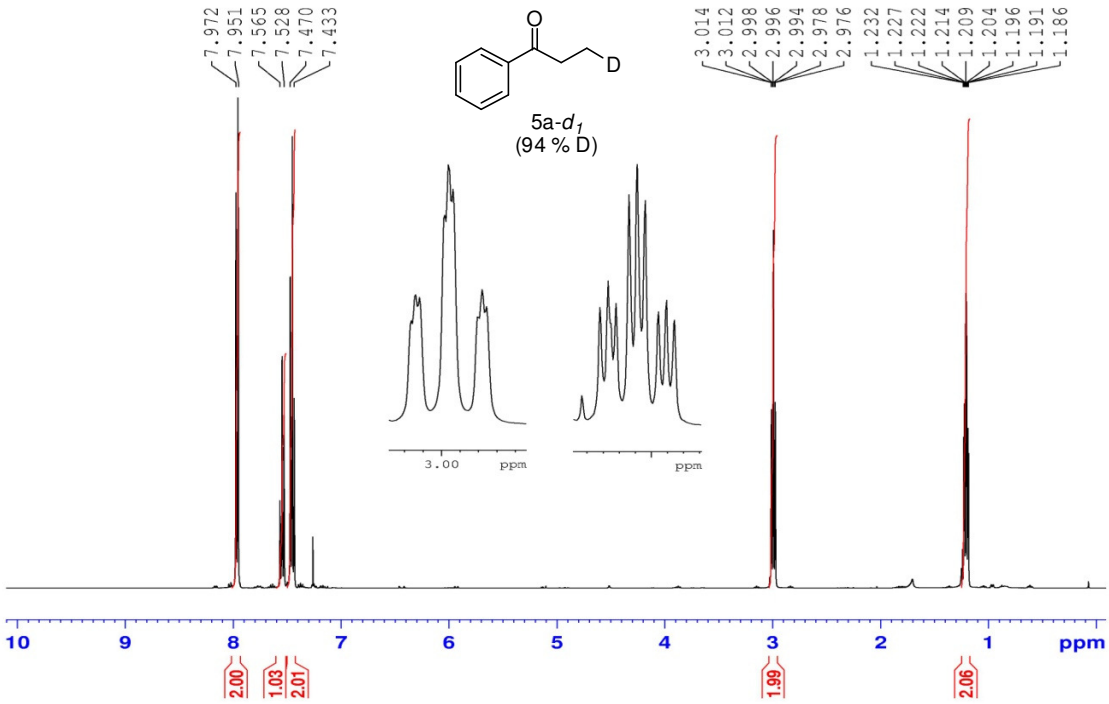
Further analysis of the third peak, P3, by HRMS showed:

HRMS-ESI: *m/z* 319.1657 ([M+Na]$^+$= $^{12}C_{20}H_{24}Na_1O_2$)(100%); calcd. m/z: 319.1669) (100%)

HRMS-ESI: *m/z* 320.1693 ([M+Na]$^+$= $^{12}C_{19}{}^{13}C_1H_{24}Na_1O_2$ (18.3%); calcd. m/z: 320.1702) (21.6%)

HRMS-ESI: *m/z* 321.1732 ([M+Na]+= $^{12}C_{18}{}^{13}C_2H_{24}Na_1O_2$ (2%); calcd. m/z: 321.1733 (2.2%)

The HRMS chromatogram of P3 showed the normal isotope distribution (*i.e*. the intensity of the peaks (M+Na), (M+Na+1) and (M+Na+2) was very similar to that obtained in a simulated spectra). These results in combination with the $^1$H and $^{13}$C NMR spectra shown below confirm the absence of deuterium incorporation in ketone **6o**. The low resolution mass spectra of peaks P1 and P2 also support these conclusions.


7.972
7.951
7.565
7.528
7.470
7.433
3.014
3.012
2.998
2.996
2.994
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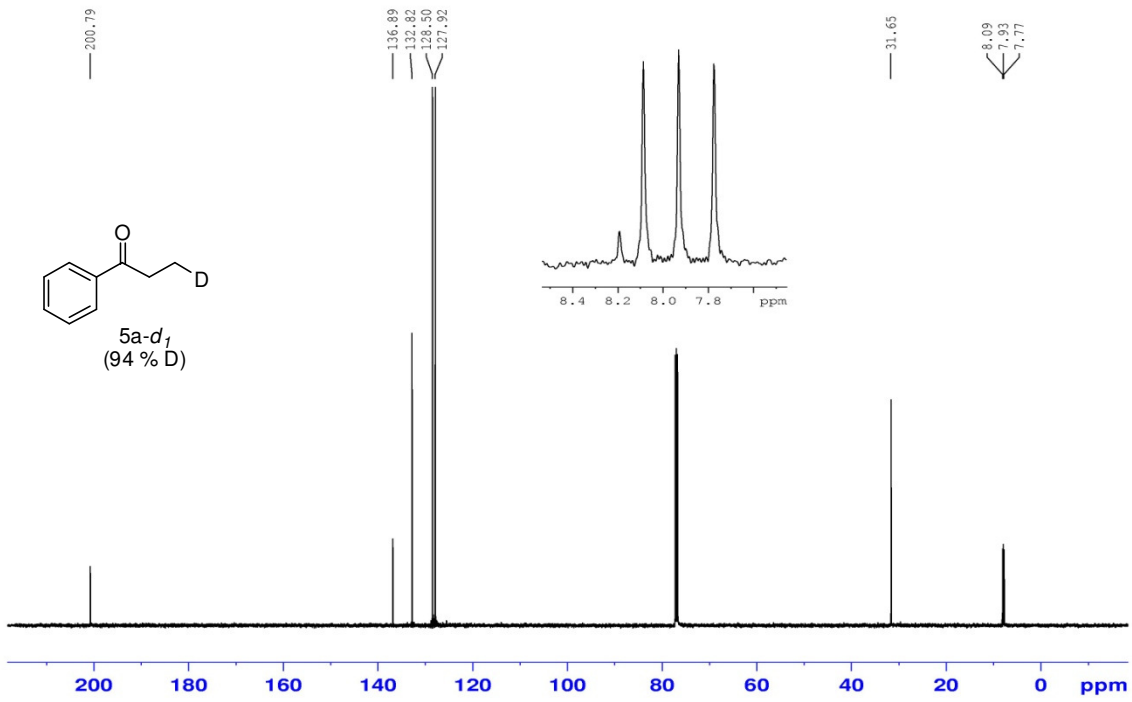
2.976
1.232
1.227
1.222
1.214
1.209
1.204
1.196
1.191
1.186
O
D
5a-d1
(94 % D)
3.00
ppm
ppm
10
9
8
7
6
5
4
3
2
1
ppm
2.00
1.03
2.01
1.99
2.06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127.92
31.65
8.09
7.93
7.77
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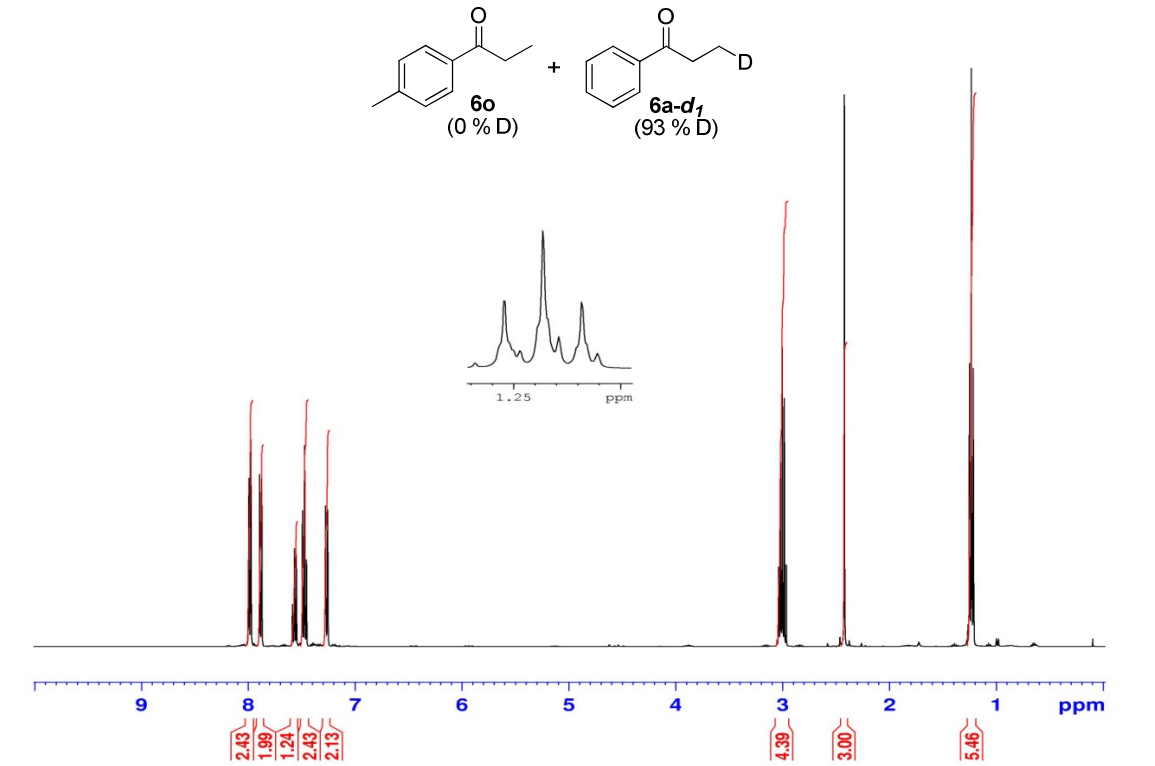
D
5a-d1
(94 % D)
8.4
8.2
8.0
7.8
ppm
200
180
160
140
120
100
80
60
40
20
0
ppm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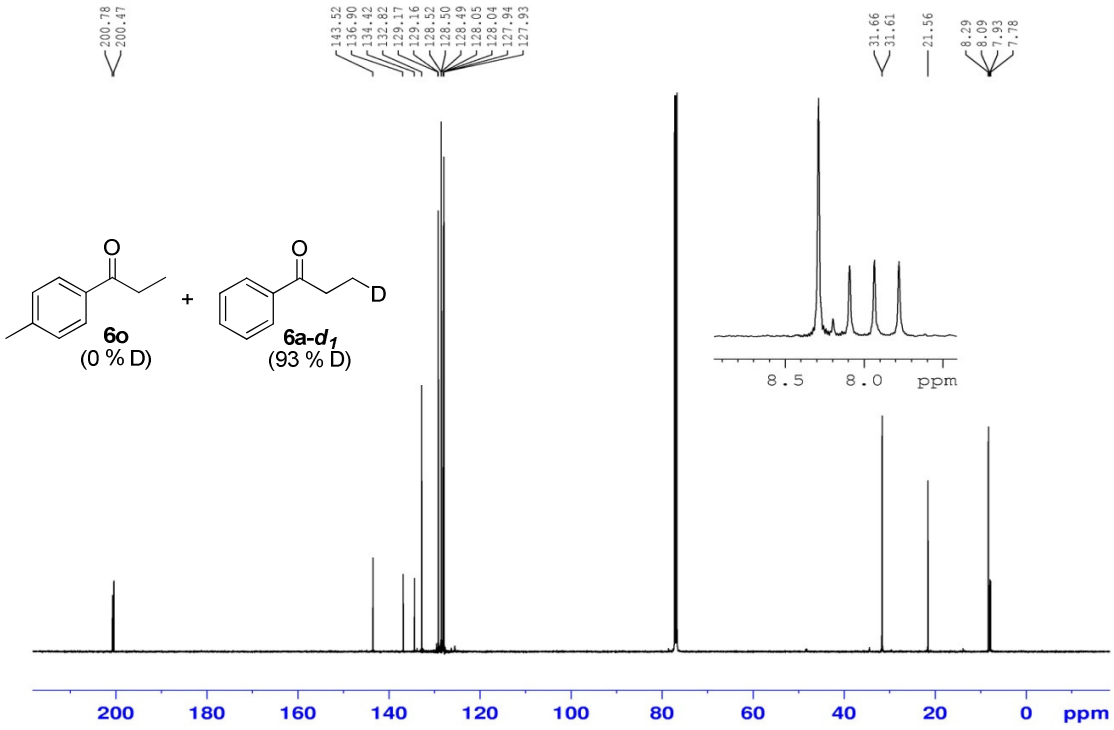
O
D
+
6o
(0 % D)
6a-d1
(93 % D)
1.25
ppm
9
8
7
6
5
4
3
2
1
ppm
2.43
1.99
1.24
2.43
2.13
4.39
3.00
5.46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128.52
128.50
128.49
128.05
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127.94
127.93
31.66
31.61
21.56
8.29
8.09
7.93
7.78
O
O
D
+
6o
(0 % D)
6a-d1
(93 % D)
8.5
8.0
ppm
200
180
160
140
120
100
80
60
40
20
0
ppm

## References

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