Supporting Information

Regioselective deuteration of alcohols in D_2O catalysed by homogeneous manganese and iron pincer complexes

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1. Materials and methods

All deuteration experiments were carried out under an inert atmosphere (with N_2 or Ar). Complexes MnBrPNP^{iPr}(CO)$_2$ (**C-1)** MnBrPNP^{Cy}(CO)$_2$ (**C-2**), and FeHBrPNP^{iPr}(CO) (**C-3**) were prepared by previously reported methods.[1,2] All catalysts were weighed inside an argon filled glove box. Alcohols **1**-**21** and NaOH were bought from commercial vendors and used without further purification. D_2O (CIL, D-99.5%) was sparged with N_2 for 1 h prior to use. ^{1}H, ^{2}H, ^{31}P and ^{13}C NMR spectra were recorded on 400 MHz or 500 MHz Varian NMR spectrometers. ^{1}H and ^{13}C NMR chemical shifts were determined relative to the residual solvent signals (D_2O, $CDCl_3$). The ^{2}H NMR chemical shift were determined based on external $CDCl_3$ reference. Mass spectral data were recorded on a Bruker 300-MS TQ Mass Spectrometer at 70 eV for EI.

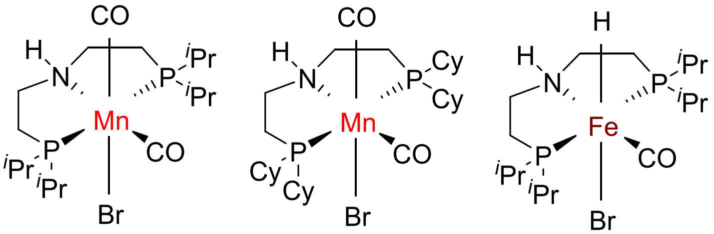

C-1 **C-2** **C-3**

Figure S1. Catalytic complexes screened in this study

2. Standard procedure for deuteration reaction

In a J. Young NMR tube (total volume ~2.5 mL), catalyst **C-1/C-2/C-3** was weighed inside an argon globe box, followed by the addition of pre-dissolved NaOH (5-200 mol% with respect to alcohol) in 0.4 mL D_2O, and alcohol (0.25-0.5 mmol) under nitrogen atmosphere (10 μL 1,4-dioxane was additionally added in case of ethanol (**2**), methanol (**3**), ethylene glycol (**13**), and isopropanol (**20**) as an internal standard). The NMR tube was then sealed and a proton NMR spectrum was recorded. Subsequently, the NMR tube was placed in a pre-heated oil bath (100 °C - 140 °C) for a given amount of time (12-60 h). After the reaction, the NMR tube was cooled to room temperature; after which the ^{1}H and ^{13}C NMR spectra were recorded. The amount of deuteration was calculated from the ^{1}H (and ^{2}H, whenever necessary) NMR spectra based on integral ratios of nondeuterable peaks (not α/β)/ internal standard peak with deuterated peaks. The deuterated alcohols were isolated through extraction with $CDCl_3$. Maximum theoretical deuteration achievable were calculated based on the numbers of exchangeable proton and deuterium atoms present in the system. For example, for Table 1, entry 1, total exchangeable H atoms = [0.5x5 (from *n*-BuOH) + 1.0 (from NaOH)] mmol = 3.5 mmol. Total exchangeable D atom = [400*1.11*2/20] (from D_2O; d= 1.11; MW = 20) = 44.4 mmol. So, the theoretical maximum deuteration = [44.4/(44.4+3.5)]*100% = 93%

3. Selected spectral data for deuteration reactions

3.1. Deuteration of primary alcohols with manganese complex C-1

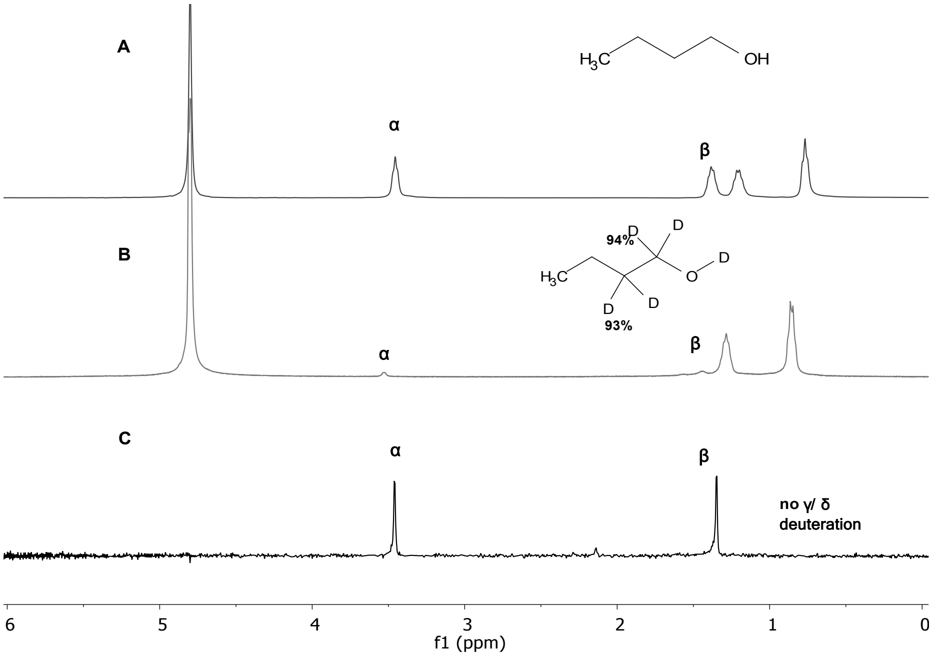


Figure S2. ^1H spectra of deuteration of 1 before (A) and after (B) reaction and ^2H spectra of deuterated *n*-butanol (C). Reaction conditions: **1** (0.5 mmol), **C-1** (1mol%), NaOH (5 mol%), D_2O (0.4 mL), 120 ^oC, 12 h.

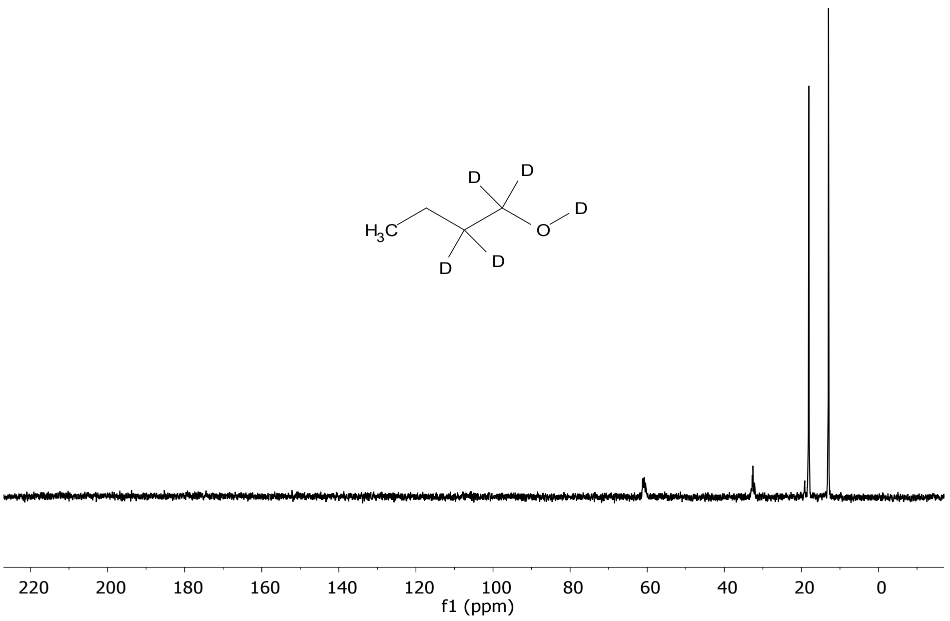


Figure S3. ^{13}C spectra of deuterated (α, β) n-butanol (1) in D$_2$O. Reaction conditions: **1** (0.5 mmol), **C-1** (1mol%), NaOH (5 mol%), D$_2$O (0.4 mL), 120 °C, 12 h.

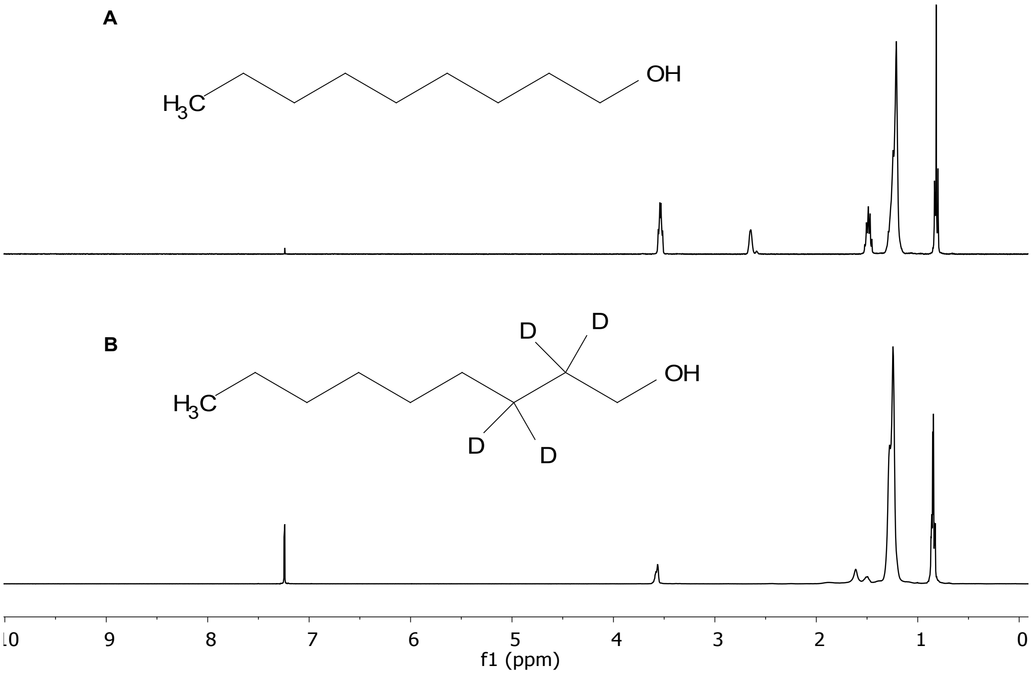


Figure S4. ^{1}H spectra of 4 before (A) and after (B) reaction. Reaction conditions: **4** (0.5 mmol), **C-1** (1 mol%), NaOH (5 mol%), D$_2$O (0.4 mL), 120 °C, 12 h.

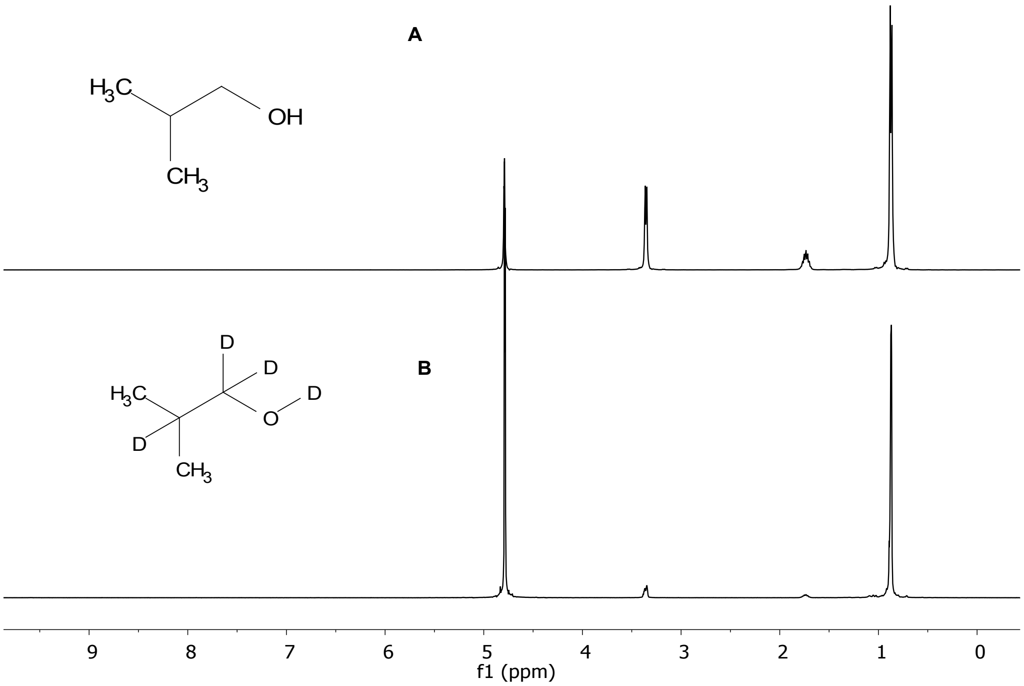


Figure S5. ^{1}H spectra of deuteration of 5 before (A) and after (B) reaction. Reaction conditions: **5** (0.5 mmol), **C-1** (0.5 mol%), NaOH (5 mol%), D_2O (0.4 mL), 120 °C, 12 h.

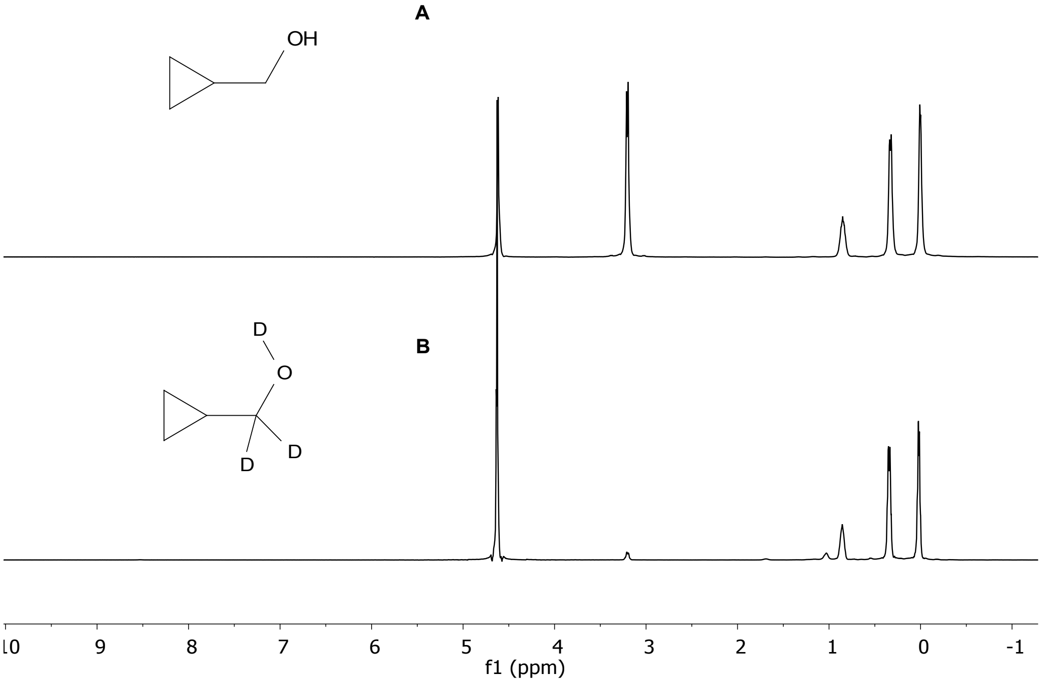


Figure S6. ^{1}H spectra of deuteration of 6 before (A) and after (B) reaction. Reaction conditions: **6** (0.5 mmol), **C-1** (0.5 mol%), NaOH (5 mol%), D_2O (0.4 mL), 120 °C, 12 h.

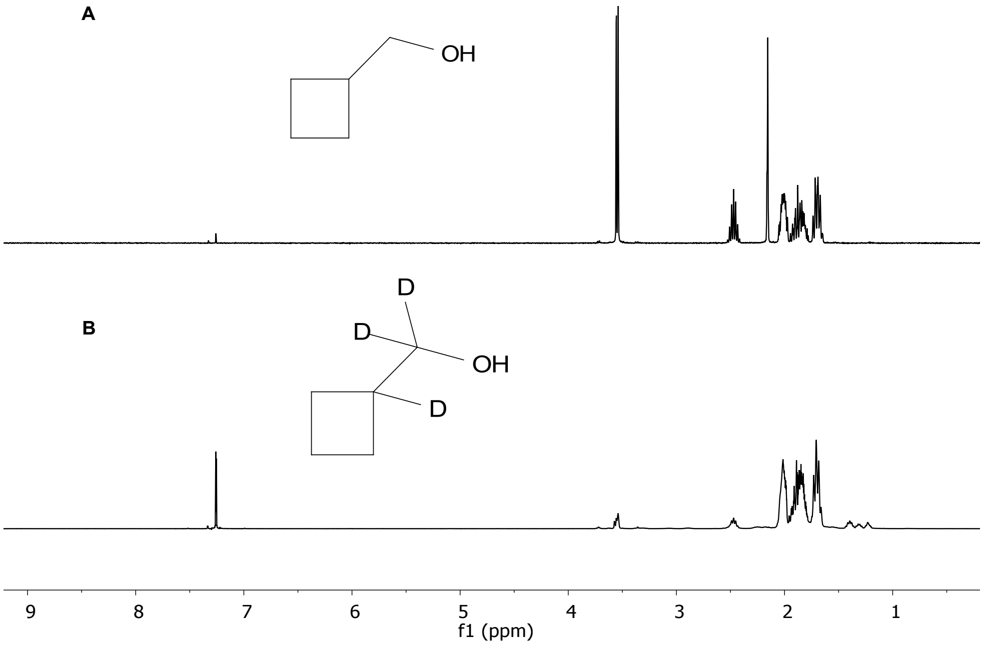


Figure S7. ^1H spectra of 7 before (A) and after (B) reaction. Reaction conditions: **7** (0.5 mmol), **C-1** (1 mol%), NaOH (5 mol%), D_2O (0.4 mL), 120 ^oC, 12 h.

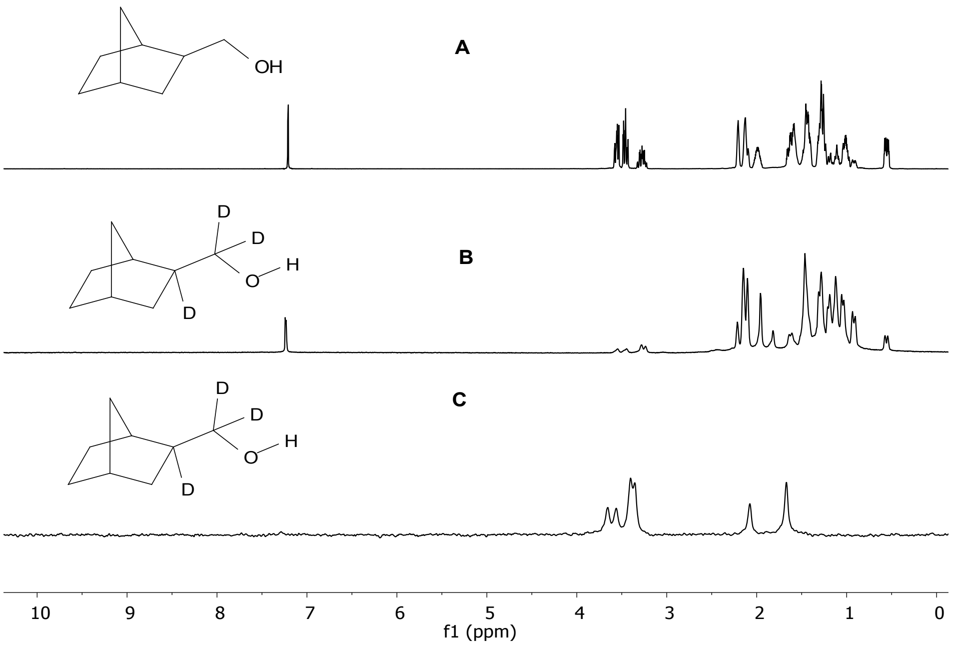


Figure S8. ^1H spectra of 9 before (A) and after (B) reaction and ^2H spectra of deuterated 9 (C). Reaction conditions: **9** (0.5 mmol), **C-1** (1 mol%), NaOH (5 mol%), D_2O (0.4 mL), 120 ^oC, 12 h.

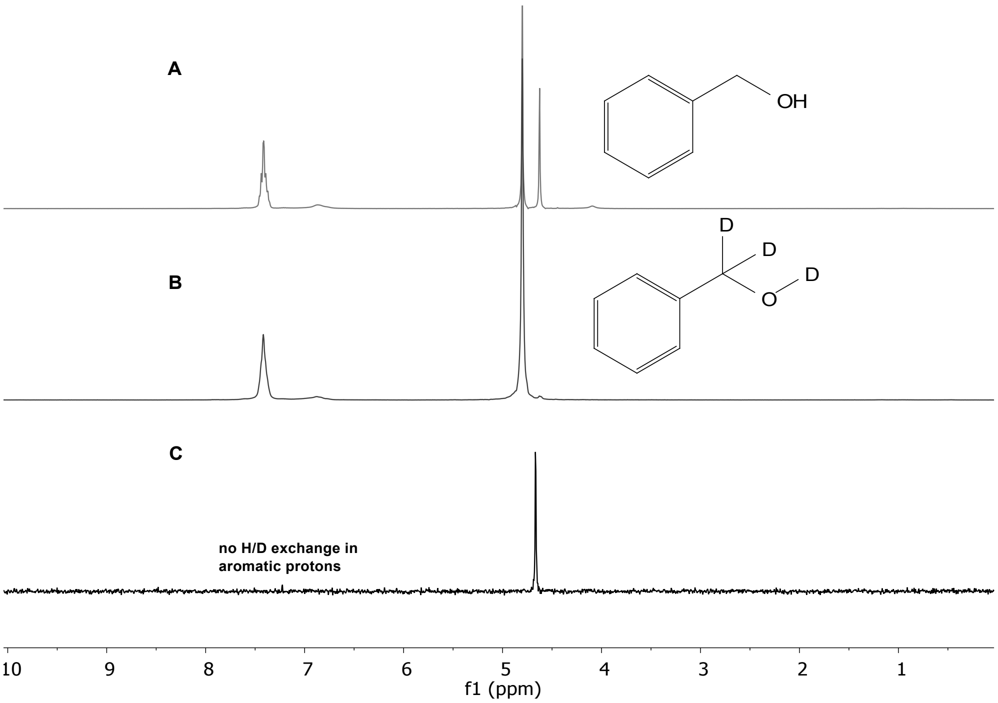


Figure S9. ^{1}H spectra of 10 before (A) and after (B) reaction and ^{2}H spectra o deuterated 10 (C). Reaction conditions: **10** (0.5 mmol), **C-1** (0.5 mol%), NaOH (5 mol%), D_2O (0.4 mL), 120 ^oC, 12 h.

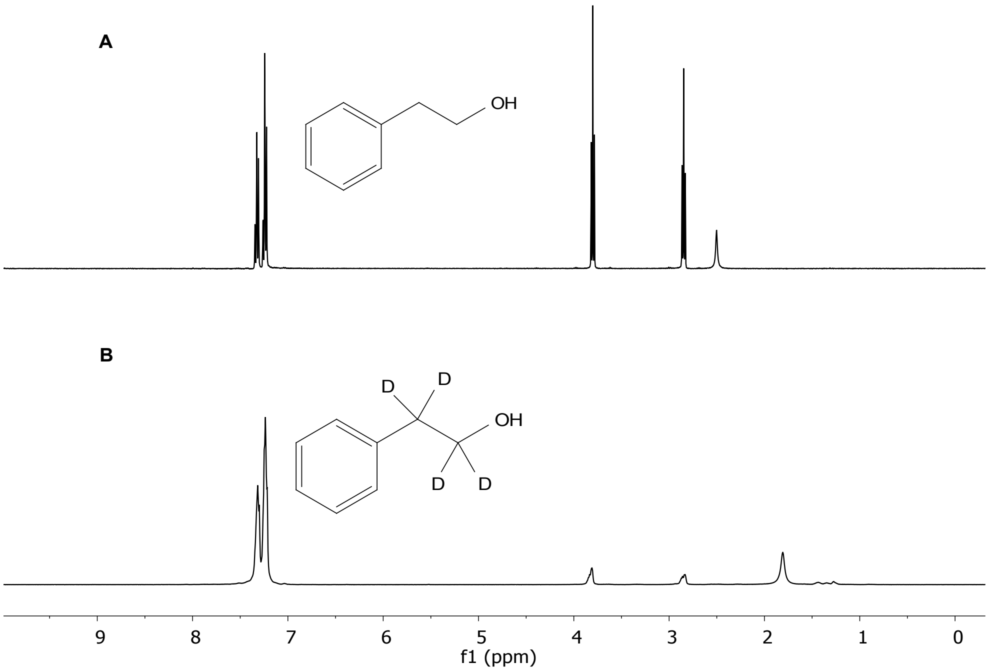


Figure S10. ^{1}H spectra of 12 before (A) and after (B) reaction. Reaction conditions: **12** (0.5 mmol), **C-1** (0.5 mol%), NaOH (5 mol%), D_2O (0.4 mL), 120 ^oC, 12 h.

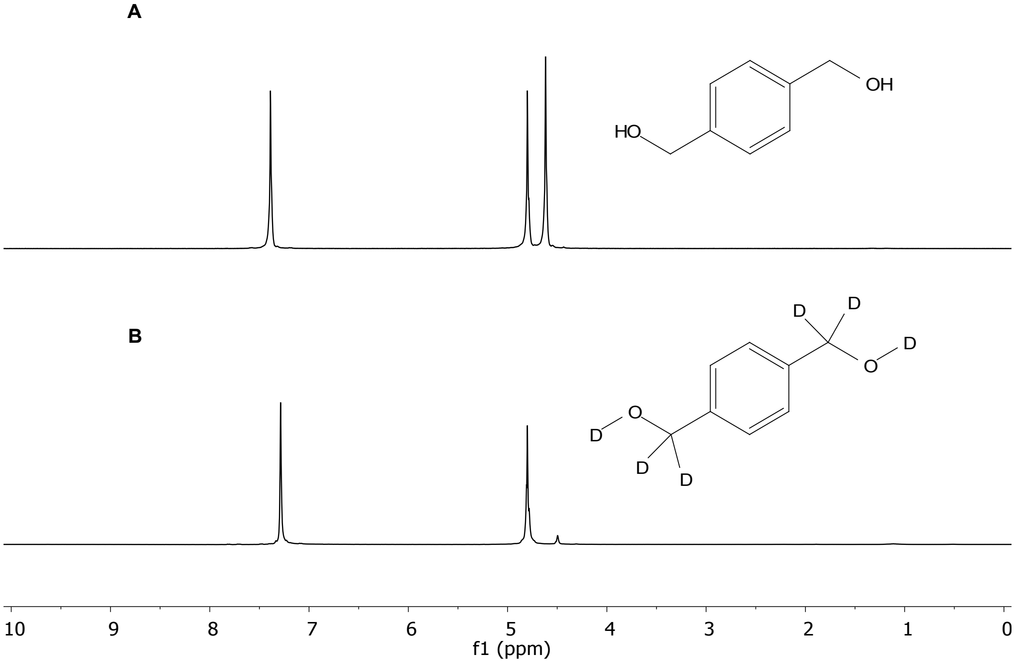


Figure S11. ^{1}H spectra of 15 before (A) and after (B) reaction. Reaction conditions: **15** (0.5 mmol), **C-1** (1 mol%), NaOH (5 mol%), D_2O (0.4 mL), 120 °C, 12 h.

3.2. Deuteration of primary alcohols with iron complex C-3

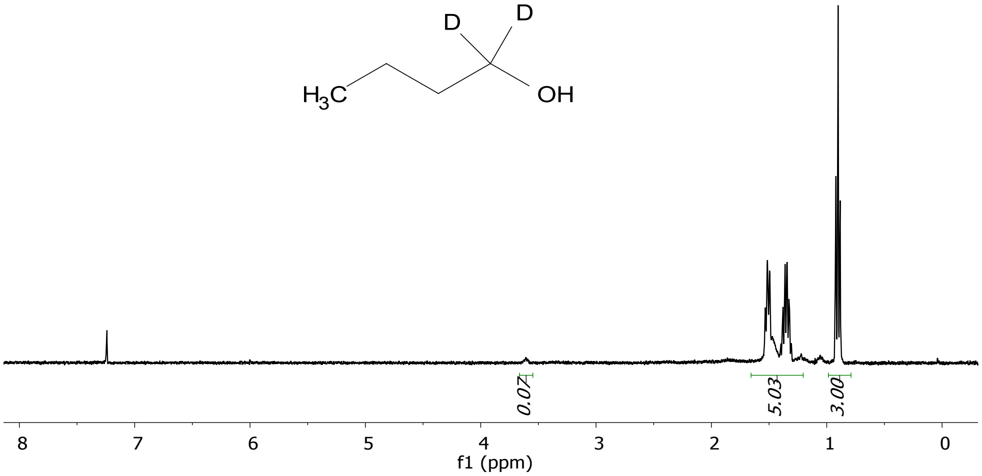


Figure S12. ^{1}H spectra of α-deuterated 1. Reaction conditions: **1** (0.25 mmol), **C-3** (2 mol%), NaOH (10 mol%), D_2O (0.4 mL), 100 °C, 24 h.

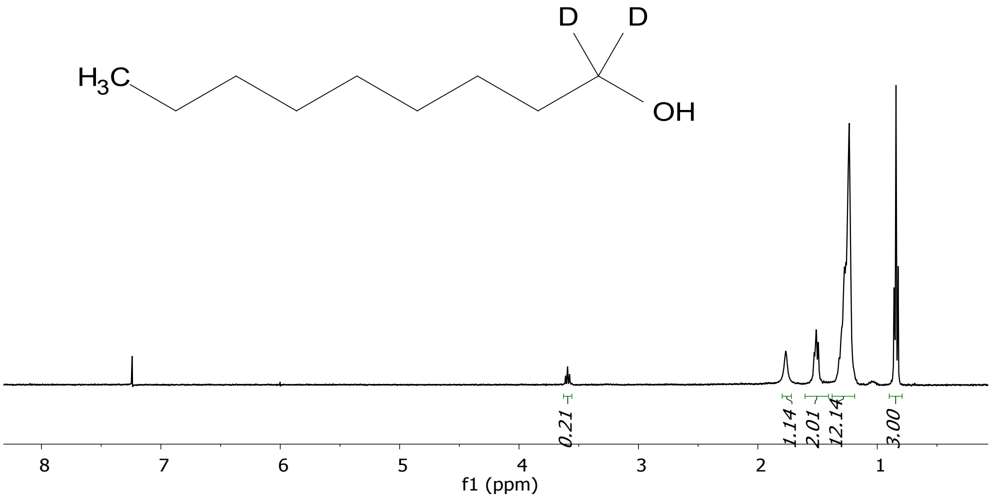


Figure S13. ^{1}H spectra of α-deuterated 4. Reaction conditions: **4** (0.25 mmol), **C-3** (2 mol%), NaOH (10 mol%), D_2O (0.4 mL), 100 ^oC, 24 h.

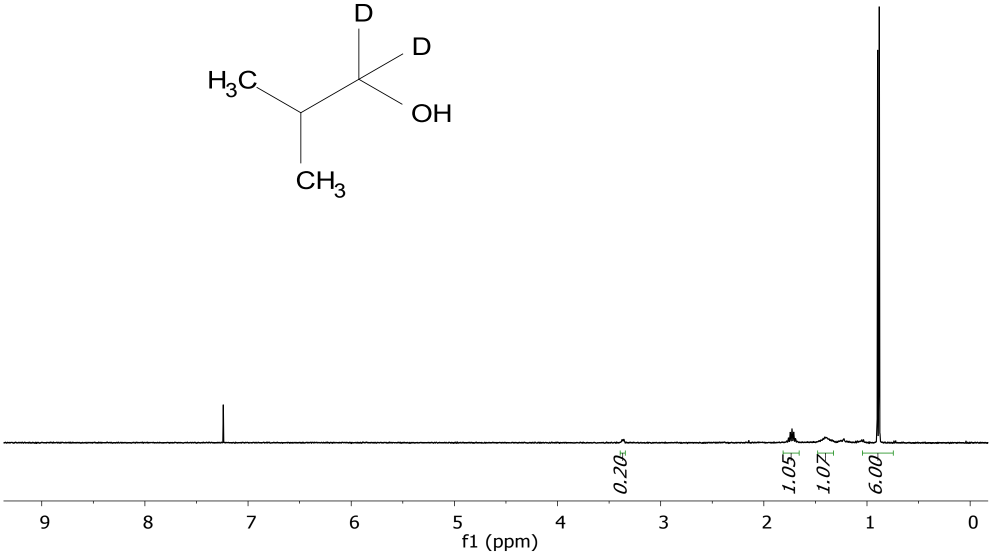


Figure S14. ^{1}H spectra of α-deuterated 5. Reaction conditions: **5** (0.25 mmol), **C-3** (2 mol%), NaOH (10 mol%), D_2O (0.4 mL), 100 ^oC, 24 h.

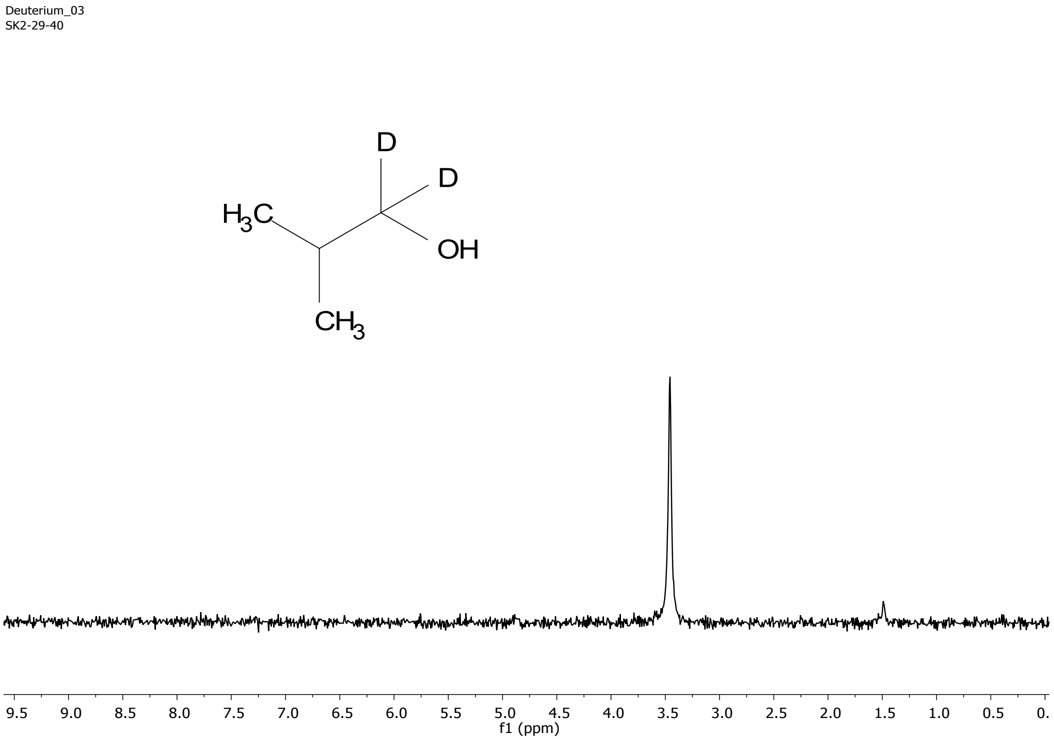


Figure S15. ^{2}H spectra of α-deuterated 5. Reaction conditions: **5** (0.25 mmol), **C-3** (2 mol%), NaOH (10 mol%), D_2O (0.4 mL), 100 °C, 24 h.

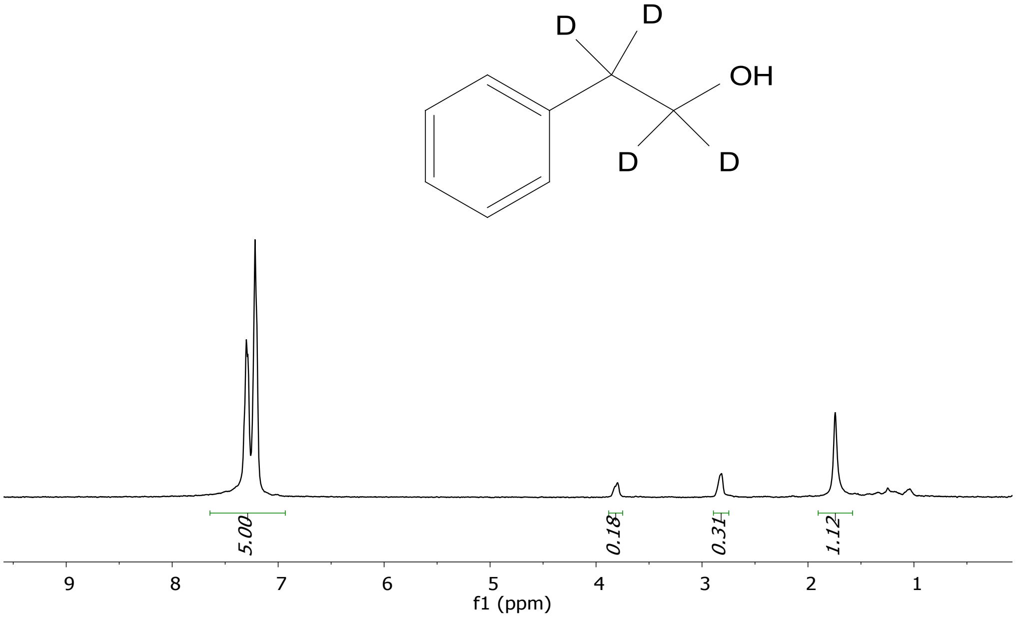


Figure S16. ^{1}H spectra of α, β-deuterated 12. Reaction conditions: **12** (0.25 mmol), **C-3** (2 mol%), NaOH (10 mol%), D_2O (0.4 mL), 100 °C, 24 h.

3.2. Deuteration of secondary alcohol

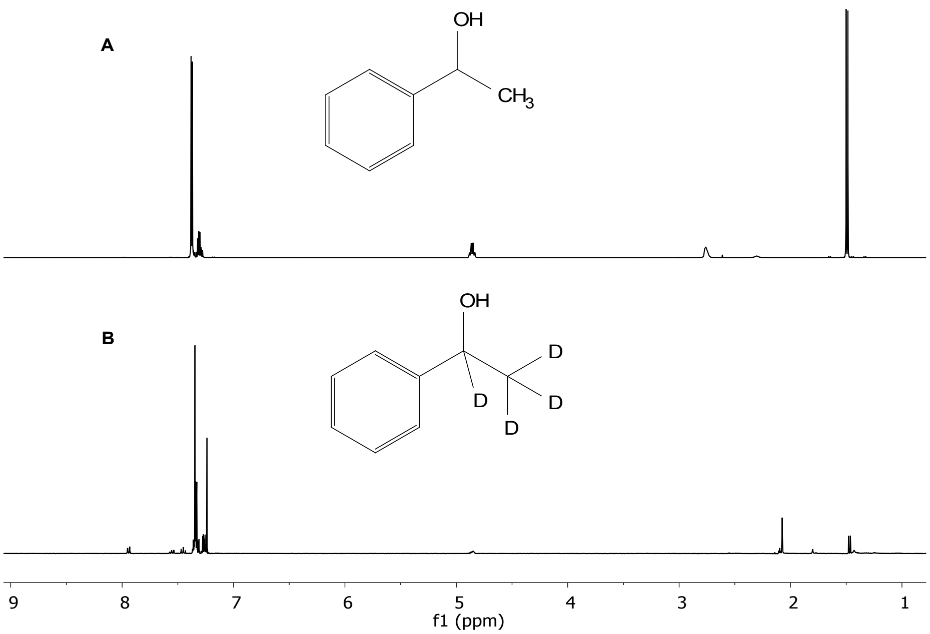


Figure S17. ^{1}H spectra of 17 before (A) and after (B) reaction. Reaction conditions: **17** (0.5 mmol), **C-1** (2 mol%), NaOH (5 mol%), D_2O (0.4 mL), 140 °C, 30 h.

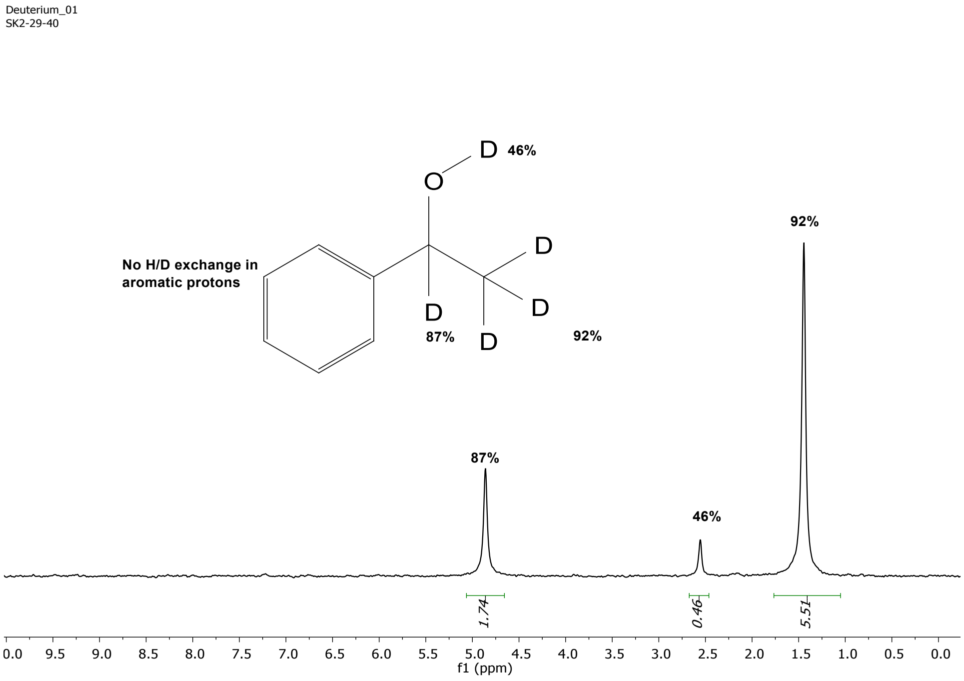


Figure S18. ^{2}H spectra of 17 after reaction. Reaction conditions: **17** (0.5 mmol), **C-1** (2 mol%), NaOH (5 mol%), D_2O (0.4 mL), 140 °C, 30 h.

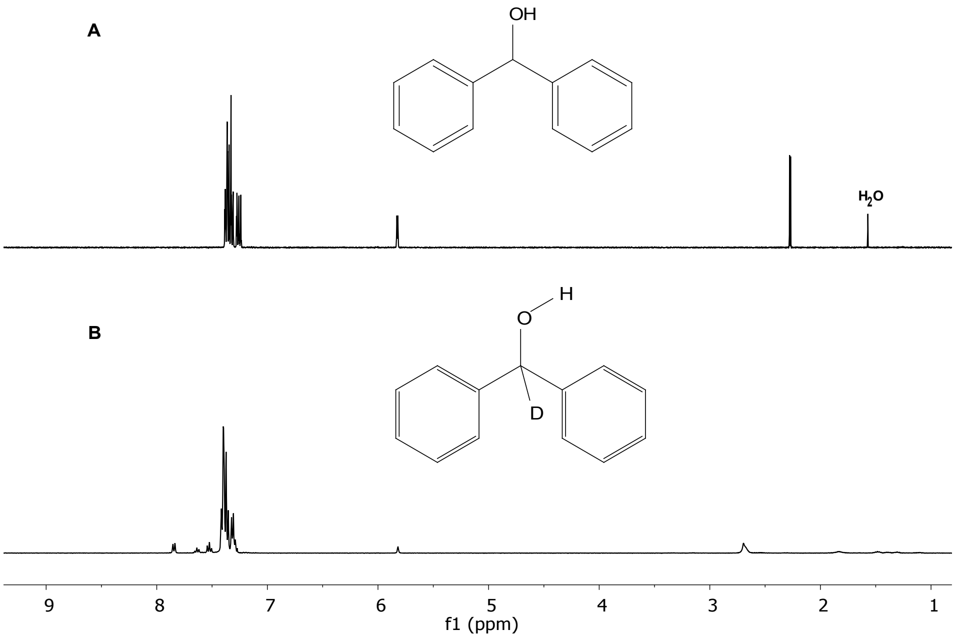


Figure S19. ^{1}H spectra of 19 before (A) and after (B) reaction. Reaction conditions: **19** (0.5 mmol), **C-1** (2 mol%), NaOH (5 mol%), D_2O (0.4 mL), 140 °C, 30 h**.**

4. Control experiments performed to understand the reaction mechanism

Observation of the active catalytic species in the reaction mixture

In a J Young NMR tube (total volume ~2.5 mL), catalyst **C-1** was weighed inside an argon globe box, followed by the addition of pre-dissolved NaOH (5 mol% with respect to alcohol) in 0.4 mL D_2O, and *n*-butanol (0.5 mmol) under nitrogen atmosphere. The NMR tube was then sealed and placed in a pre-heated oil bath (120 °C). After 1 h, the NMR tube was cooled to room temperature and 0.2 mL THF was added to the reaction mixture. The resultant homogeneous solution was then analyzed by ^{31}P NMR spectroscopy.

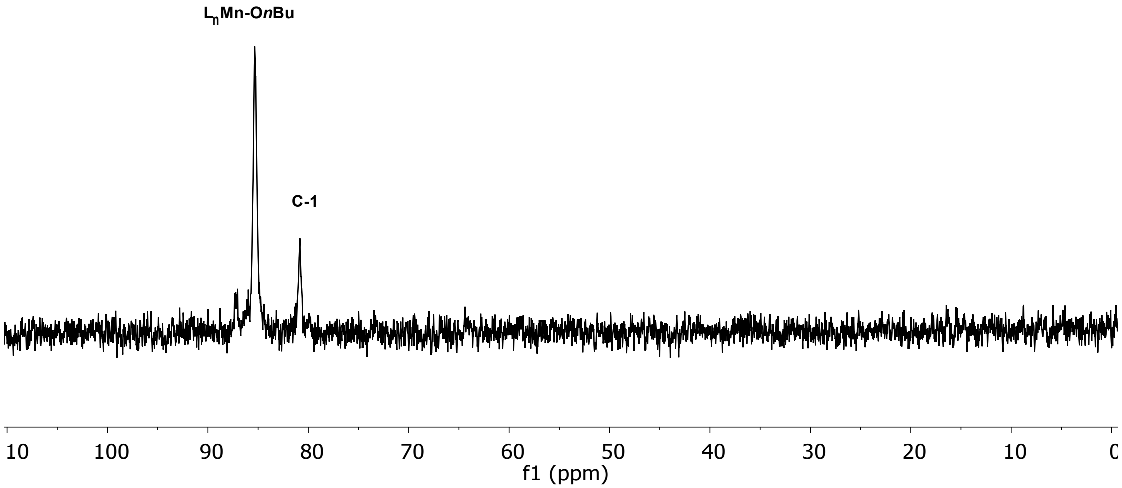


Figure S20. Active species detected in the reaction mixture through ^{31}P NMR after 1 h (0.2 mL THF was added to the reaction mixture to form a homogeneous solution)

Formation of manganese deuteroxide species (C-1B)

In a 50 mL Schlenk flask, **C-1** (0.05mmol) was weighed inside an argon glove box and subsequently dissolved in 5 mL of dry and degassed THF in a nitrogen atmosphere, followed by the addition of 1 mmol of *t*-BuOK (weighed inside an argon glove box). The formation of the manganese amido complex (**C-1A**) was observed as a red solution. After stirring the resulting solution for 15 minutes, the red solution was filtered through Celite, and 5 mmol D_2O was subsequently added to the filtrate. The solution immediately turned yellow, signifying the formation of a deuteroxide species. The solution was stirred for 30 minutes, after which the solvents were removed *in vacuo*. Benzene-d_6 was used as the deuterated solvent for the ^{31}P NMR analysis of the resulting **C-1B**.

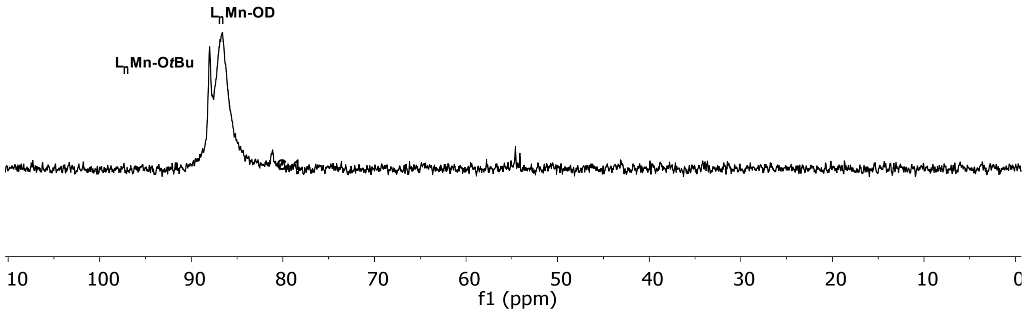
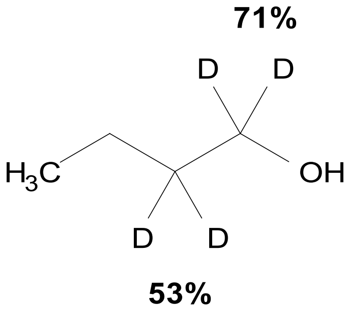


Figure S21. ^{31}P spectra of manganese deuteroxide species [Mn(OD)PN$_D$P^{iPr}(CO)$_2$] (**C-1B**).

α, β deuteration of n-butanol with C-1B



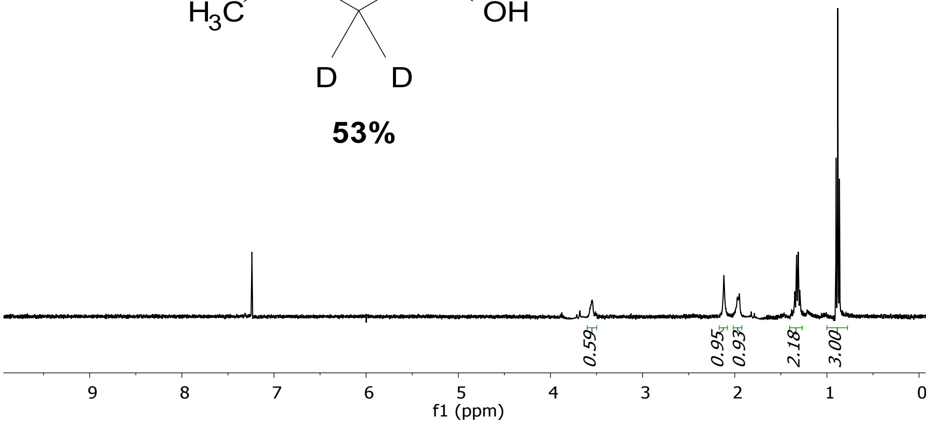


Figure S22. Deuteration of 1 by manganese deuteroxy complex (C-1B) without added base, Signifying the ability of **C-1B** to form **C-1A** in the solution at 120 °C. (THF peaks suppressed)

5. EI-MS analysis of benzyl alcohol before and after deuteration

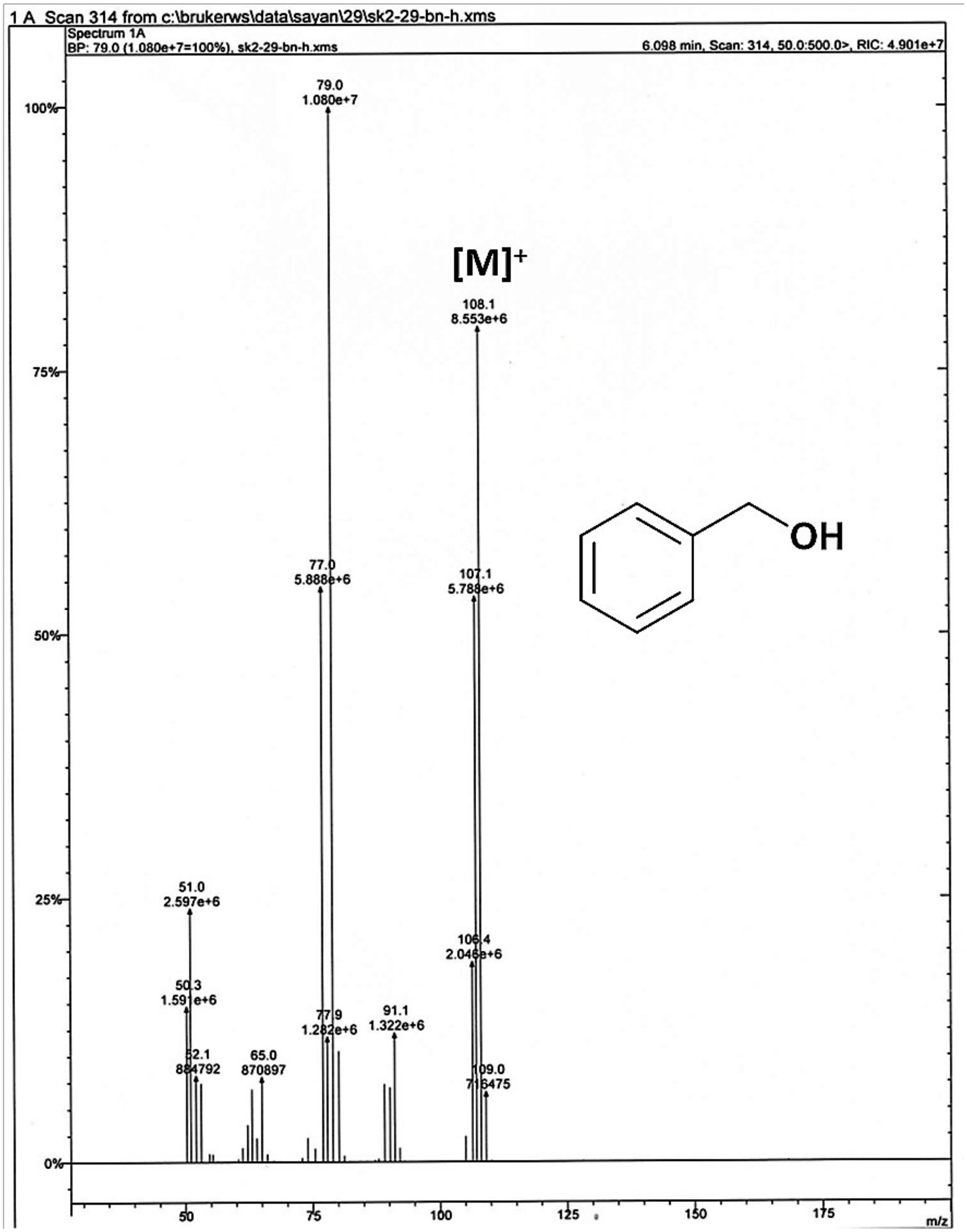


Figure S23. EI-MS spectra of benzyl alcohol

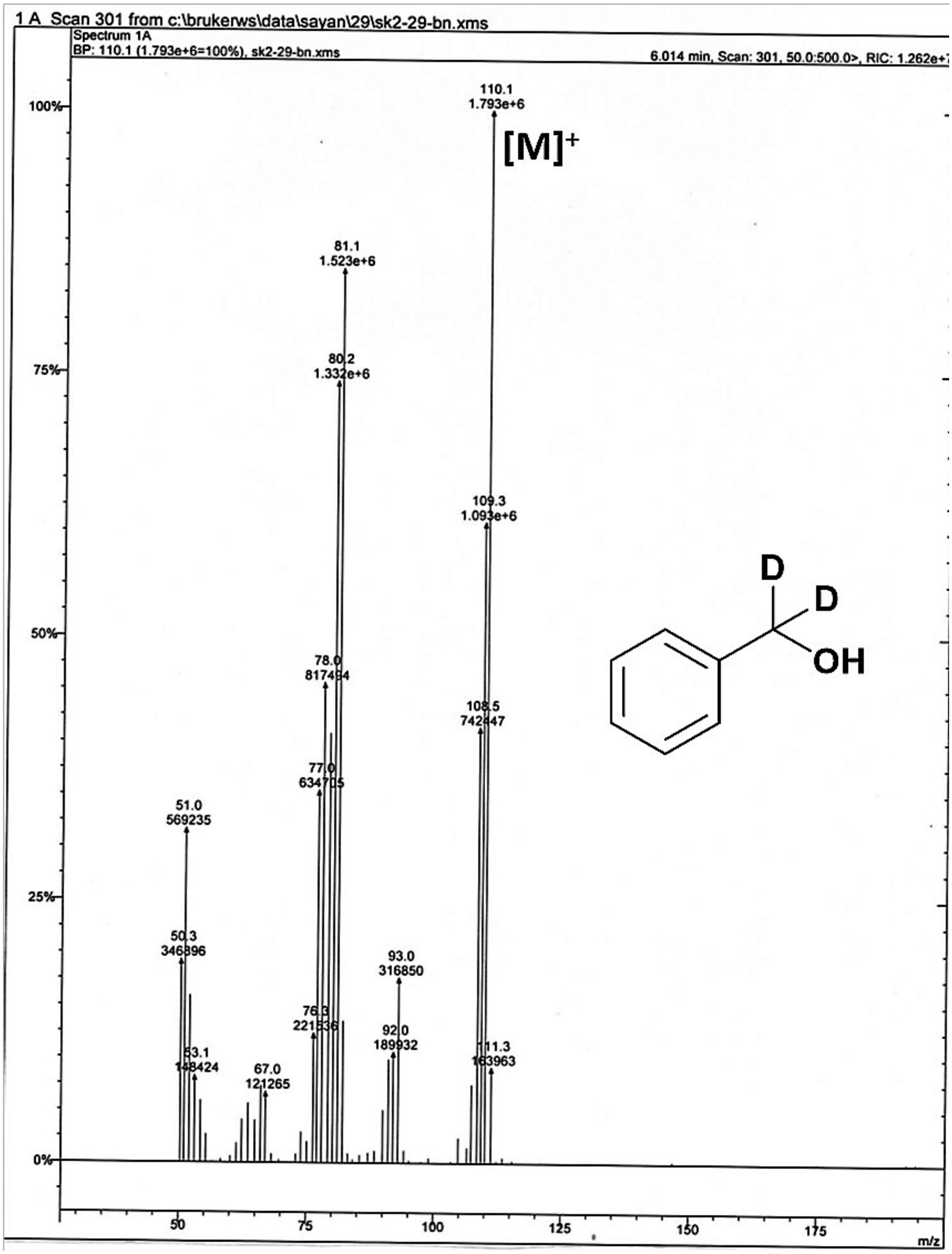


Figure S24. EI-MS spectra of α deuterated benzyl alcohol. Reaction conditions: benzyl alcohol (0.5 mmol), **C-1** (0.5 mol%), NaOH (5 mol%), D_2O (0.4 mL), 120 °C, 12 h.

6. Recycling studies

Standard procedure:

In a J. Young NMR tube (total volume ~2.5 mL), catalyst **C-1** (2 mol%, 0.01 mmol) was weighed inside an argon globe box, followed by the addition of pre-dissolved NaOH (5 mol% with respect to alcohol) in 0.5 mL D_2O, and alcohol (0.5 mmol) under nitrogen atmosphere. The NMR tube was then sealed and a proton NMR spectrum was recorded. Subsequently, the NMR tube was placed in a pre-heated oil bath (120 ^oC) for a given amount of time (12 h). After the reaction, the NMR tube was cooled to room temperature; after which a ^1H NMR spectra was recorded. Subsequently, in a nitrogen atmosphere, 0.4 mL of degassed chloroform was added to the NMR tube. From the resulting biphasic solution, the top D_2O (with NaOH) layer was separated to afford a yellow solution. The catalyst was then recovered by removing the deuterated *n*-BuOH and $CHCl_3$ in vacuo. The recovered catalyst inside the J. Young NMR tube then recharged with fresh *n*-BuOH (0.5 mmol), NaOH (5 mol%) and D_2O (0.5 mL) for the next cycle.

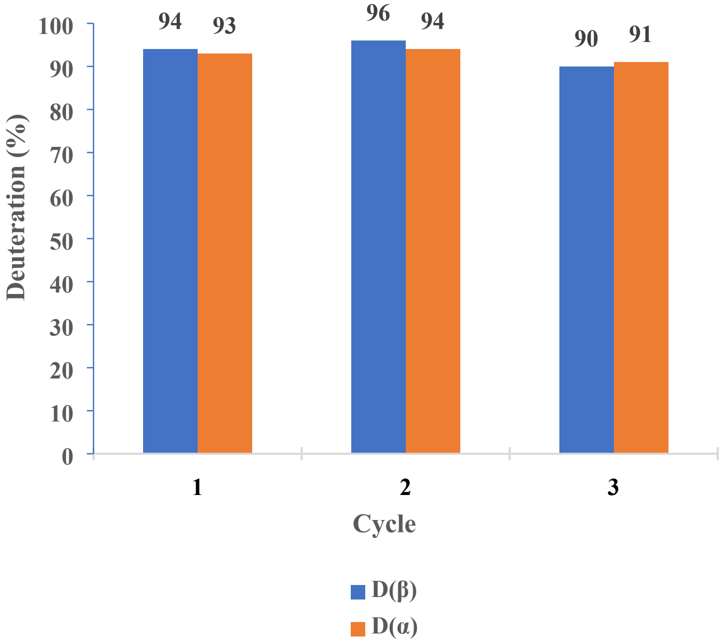


Figure S25. α and β deuteration observed in successive cycles. *n*-butanol (0.5 mmol), **C-1** (2 mol%), NaOH (5 mol%), D_2O (0.5 mL), 120 ^oC, 12 h.

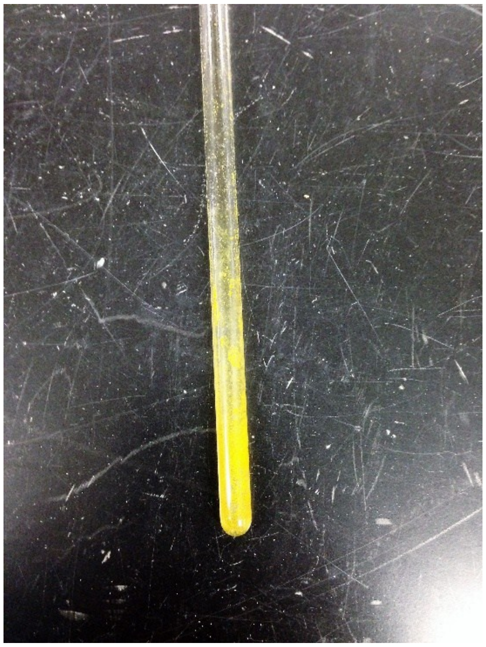


Figure S26. Image of the recovered catalyst inside the J.Young NMR tube

7. References

1. Elangovan, S.; Topf, C.; Fischer, S.; Jiao, H.; Spannenberg, A.; Baumann, W.; Ludwig, R.; Junge, K.; Beller, M. *J. Am. Chem. Soc.* **2016,** *138*, 8809–8814.

2. (a) Kothandaraman, J.; Goeppert, A.; Czaun, M.; Olah, G. A.; Prakash, G. K. S. *Green Chem.* **2016,** *18* (21), 5831-5838. (b) S. Chakraborty, H. Dai, P. Bhattacharya, N. T. Fairweather, M. S. Gibson, J. A. Krause and H. Guan, *J. Am. Chem. Soc.* **2014**, 136, 7869-7872.