Supporting Information

Mechanochemical Deutero-Dehalogenation of Aryl Halides and Fluorosulfates with Activated Aluminum

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Contents

1. General Information

Cautions!

The protocol contains a mechanochemical process, which generate H_2 gas during the grinding. **Special attention should be paid to the vessel opening, in order to avoid reaction mixture spray, potential H_2 gas explosion, and other pyrophoric behavior.**

Experiments and Reagents

Unless noted otherwise, all **mechanochemical experiments** were carried out in stainless steel vessel with stainless steel balls as grinding intermediates. The vessel was sealed with a polytetrafluoroethylene O-ring, and was shaken by an MM400 mix miller provided by Retsch GmbH. The miller is kept in a thermostat oven setting at 30 °C to unify the starting temperature of each experiment. All the reactants were weighed in open-air, and the vessels and grinding balls were dried in conventional oven at 50 °C, where no specific desiccation was paid to eliminate the moisture. The **solution reactions** were conducted under air, with oven-dried glassware and magnetic stirring bar. The D_2O for solution reactions was fetched and transferred to the reaction under a nitrogen atmosphere.

Commercially available reagents were purchased from Aladdin, Bidepharm, and Leyan Chemicals, which was used directly without further purification unless stated otherwise. The deuterated solvents were supplied by Ningbo Cuiying Chemicals. Aluminum foil obtained from chemical suppliers was used directly without treatment, and **the conventional cans from coke or other soft drink could also be used directly**.

TLC and Chromatography

Analytic thin-layer chromatography (Leyan chemicals) was used for checking the formation of unexpected side reactions. Visualization was achieved by ultraviolet light (254 nm and 365 nm) and iodine staining. Flash chromatography was performed on silica gel (200-300 mesh) with the indicated solvent systems.

Spectroscopy Analysis

The gas chromatography-mass spectroscopy (GC-MS) are recorded on an Agilent 6890N GC-system with an Agilent 5973Network Mass Selective Detector (electron ionization), and a HP-5MS column (30 m, 0.25 mm × 0.25 μm). Liquid chromatography–mass spectrometry (LC-MS) is recorded on an Agilent G6125B quadrupole LC/MS system.

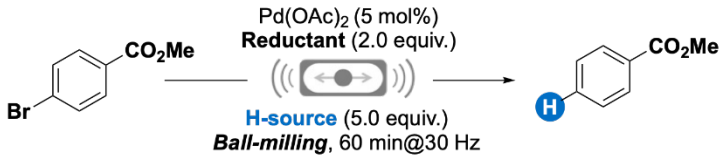
^{1}H NMR (400 MHz) are recorded on a Bruker Ascend 400 spectrometer and chemical shifts are reported in ppm down field from TMS and are referenced to residual proton in $CDCl_3$ or DMSO-d_6. The spectra for deuterated substrates are reported as observed, while the integration difference less than 5% are ignored. The NMR data are reported as: s =singlet, d = doublet, t = triplet, q = quartet, m = multiplet with *J* = coupling constant in Hz, and **the deuterated position are marked as "Labeled"**.

Calculation of Deuterium Incorporation

The degree of deuterium-incorporation was calculated based on both GC-MS and ^{1}H-NMR methods, which had been described in our previous work.[1]

2. Condition optimization

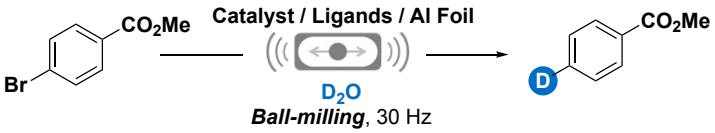
Table S1 Examination of reductants [a]



entry	catalyst (mol%)	reductant (equiv.)	H-source (equiv.)	%yield[b]
1	$Pd(OAc)_2$ (5)	Al foil [c] (2)	H_2O (5)	**91**
2	$Pd(OAc)_2$ (5)	Al foil [d] (2)	H_2O (5)	**92**
3	$Pd(OAc)_2$ (5)	Mg turning (2)	H_2O (5)	**98**
4	$Pd(OAc)_2$ (5)	Mg turning (1)	H_2O (5)	53
5	$Pd(OAc)_2$ (5)	Fe powder (0.5)	H_2O (5)	trace
6	$Pd(OAc)_2$ (5)	Zn foil (1)	H_2O (5)	10
7	$Pd(OAc)_2$ (5)	Zn foil (2)	H_2O (5)	14
8	$Pd(OAc)_2$ (5)	Ni foil (0.5)	H_2O (10)	trace
9	$Pd(OAc)_2$ (5)	HCOOH (2)		trace
10	$Pd(OAc)_2$ (5)	$HCOONH_4$ (2)		trace
11	$Pd(OAc)_2$ (5)	*i*-PrOH (2)		trace
12	$Pd(OAc)_2$ (5)	*n*-PrOH (2)		trace
13	$Pd(OAc)_2$ (5)	Na_2SO_3 (1)	H_2O (5)	trace
14	$Pd(OAc)_2$ (5)	$NaHSO_3$ (1)	H_2O (5)	trace
15	$NiCl_2$ (5)	Mg turning (2)	H_2O (5)	9
16	$Pd(OAc)_2$ (5)	Mg turning (2)	MeOH (5)	trace
17	$Pd(OAc)_2$ (5)	Al foil [d] (2)	MeOH (5)	trace
18	$Pd(OAc)_2$ (5)	Al foil [d] (2)	EtOH (5)	n.d.
19	$Pd(OAc)_2$ (5)	Al foil [d] (2)	*i*-PrOH (5)	n.d.
20	-	Mg turning (2)	H_2O (5)	n.d.
21	-	Al foil [d] (2)	H_2O (5)	n.d.
22[e]	$Pd(OAc)_2$ (5)	Al foil [d] (2)	H_2O (5)	90
23[f]	$Pd(OAc)_2$ (5)	Al foil [d] (2)	H_2O (5)	93

[a] Reaction condition unless noted otherwise: methyl 4-bromobenzoate **1** (1 mmol), catalyst, reductant and H-source in a 10 mL stainless-steel vessel with stainless-steel ball (1.5 cm x 1), started at ambient temperature of 30 °C, grinding at frequency of 30 Hz; [b] Yield determined by HPLC; [c] The aluminum foil was from Coca-Cola can; [d] Chemical purity; [e]stainless-steel ball (1.2 cm x 2); [f]stainless-steel ball (0.9 cm x 3). n.d. = not detected.

Table S2 Condition optimization [a]



entry	Catalyst (mol%)	Ligand (mol%)	Al (equiv.)	D_2O (equiv.)	Time (min)	%yield [b]	D_{MS} [c]
1	**$PdCl_2$ (1)**	none	2	5	60	53	0.78
2	**$Pd(TFA)_2$ (1)**	none	2	5	60	54	0.84
3	**$Pd(PPh_3)_4$ (1)**	none	2	5	60	trace	n/a
4	**$Pd(PPh_3)_2Cl_2$ (1)**	none	2	5	60	trace	n/a
5	**$Pd(OAc)_2$ (1)**	none	2	5	60	65	0.76
6	$Pd(OAc)_2$ (1)	**JohnPhos (2)**	2	5	60	44	0.8
7	$Pd(OAc)_2$ (1)	**DavePhos (2)**	2	5	60	trace	n/a
8	$Pd(OAc)_2$ (1)	**XPhos (2)**	2	5	60	54	0.85
9	$Pd(OAc)_2$ (1)	**SPhos (2)**	2	5	60	42	0.81
10	$Pd(OAc)_2$ (1)	**PCy_3 (2)**	2	5	60	trace	n/a
11	$Pd(OAc)_2$ (1)	**$PCyPh_2$ (2)**	2	5	60	trace	n/a
12	$Pd(OAc)_2$ (1)	**MePhos (2)**	2	5	60	12	0.83
13	$Pd(OAc)_2$ (1)	**TMG (2)**	2	5	60	63	0.82
14	$Pd(OAc)_2$ (1)	none	2	5	**10**	25	0.77
15	$Pd(OAc)_2$ (1)	none	2	5	**20**	31	0.87
16	$Pd(OAc)_2$ (1)	none	2	5	**40**	53	0.81
17	$Pd(OAc)_2$ (1)	none	2	5	**50**	71	0.76
18	$Pd(OAc)_2$ (1)	none	2	5	**70**	72	0.71
19	$Pd(OAc)_2$ (1)	none	2	5	**90**	72	0.88
20	$Pd(OAc)_2$ **(3)**	none	2	5	60	71	0.81
21	$Pd(OAc)_2$ **(5)**	none	2	5	60	77	0.86
22	$Pd(OAc)_2$ (5)	none	**1**	5	60	64	0.85
23	$Pd(OAc)_2$ (5)	none	**1.5**	5	60	70	0.83
24	$Pd(OAc)_2$ (5)	none	**3**	5	60	73	0.86
25	$Pd(OAc)_2$ (5)	none	**none**	5	60	trace	n/a
26	none	none	2	5	60	11	0.76
27	$Pd(OAc)_2$ (5)	none	**2**	**10**	**60**	**90**	**0.90**
28[d]	$Pd(OAc)_2$ (5)	none	2	10	60	< 5	0.87
29[d,e]	$Pd(OAc)_2$ (5)	none	2	10	60	< 5	0.85

[a] Reaction condition unless noted otherwise: methyl 4-bromobenzoate **1** (1 mmol), catalyst, ligand, Al foil and D_2O in a 10 mL stainless-steel vessel with stainless-steel ball (1.5 cm x 1), started at ambient temperature of 30 °C, grinding at frequency of 30 Hz; [b] Yield determined by HPLC; [c] Deuterium incorporation determined by GC-MS; [d] PTFE vessel and ZrO_2 ball (1.2 cm x 1); [e] 10 mg stainless-steel powder added.

3. General procedure

General procedure for mechanochemical reaction: A mixture of aromatic halide (1.0 equiv.), aluminum foil (2.0 equiv.), $Pd(OAc)_2$ (5 mol %), and D_2O (10.0 equiv.) were added to the 10 mL screw-capped stainless steel vessel, along with one stainless steel ball (ø = 1.5 cm). The vessel was placed in the mixer mill and milled at 30 Hz for 60 min within a thermostat oven at 30 °C. At the end of the reaction, ethyl acetate (4 mL) was added into the vessel and grinding for another 10 - 20 seconds at 30 Hz, which was then filtered. The filtrate was dried over sodium sulfate and concentrated in vacuo to give a residue, which was purified by flash column chromatography on silica gel (eluents: n-hexane/ethyl acetate) to give the desired product.

Figure S1 Mix-miller placed in a thermostat oven to ensure the starting temperature.

Note: The thermostat oven was used to increase the data reproducibility avoiding the interference from ambient temperature. A much longer reaction time and lower yield could be expected with the room temperature below 15 °C.

4. Mechanistic Investigation

a) Mechanistic analysis of possible pathways

According to the potential role of aluminum in this transformation, three possible mechanism was proposed based on previous literature reported. The possible pathway was depicted in Figure S2, and the potential step of aluminum participation was denoted with a sign of Al.

i. Firstly, due to the high reductive potential of aluminum, single-electron transfer (SET) could be expected to occur,[2] cleaving C-X bond to generate an aromatic cation radical. The intermediate could be further reduced via another SET to afford an aromatic anion, which could fetch a proton (deuteron) from hydrogen source.

ii. The reaction could also be conducted via an organometallic intermediate mimicking the Grignard reagent. Due to the unexplored nature of mechanochemical process, several novel chemistry had been shown via this unique technique, including Grignard reagent of fluorides,[3] as well as the mechanochemical intermediate.[4] Therefore, the transformation may conduct via a Grignard-type route, generating organoaluminum species during the grinding, followed by a protonolysis to afford the desired product.

iii. Due to the necessity of Pd-catalyst in the condition optimization, it is more plausible that the reaction conduct via a classical Pd-catalyzed route. However, the aryl palladium species, generated via oxidative addition, may undergo two different transformation such as protonolysis and hydride-transfer. The catalytic cycle of former could be closed by a reduction of Pd^{2+} species to Pd^0. While the hydride-transfer still face the problem of the provider of the hydride species.

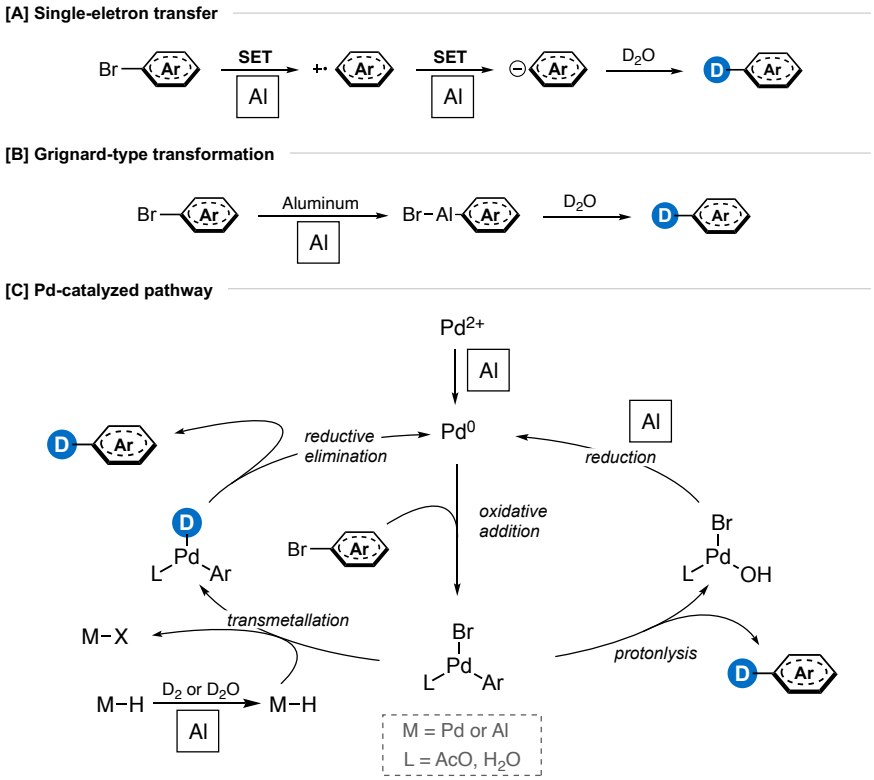
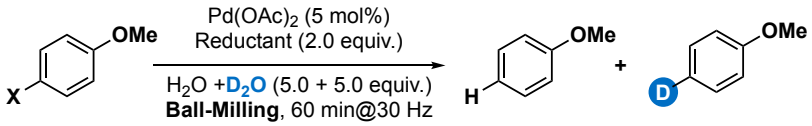


Figure S2 Possible mechanistic pathway for aluminum-mediated mechanical deutero-dehalogenation

b) Kinetic isotope effects experiments

To measure the kinetic isotope effect, a comparison experiment was conducted using a mixture of H/D-source of 1:1 ratio. As expected, the reaction showed a KIE value around 4.0, which was similar as previous works of deutero-dehalogenation of alkyl halides.[5] We also tested the KIE using magnesium as reductant, as well as aryl chloride as substrate. Both reactions showed similar KIE value, indicating the step water activation was accounted for the rate determining step.

Another reaction was conducted using a H/D ratio of 1:9. The reaction showed an astonishing consumption priority of water. The product showed a deuterium incorporation of 61%, which is far from the theoretical H/D ratio.

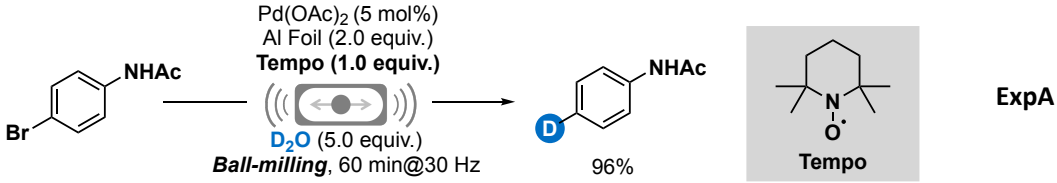


X = Br	Reductant = Al Foil	H:D = 81:19	k_H/k_D = 4.3
X = Br	Reductant = Mg Turning	H:D = 75:25	k_H/k_D = 3.0
X = Cl	Reductant = Al Foil	H:D = 82:18	k_H/k_D = 4.6

Procedure for KIE experiments: A mixture of 4-bromo-anisole (187 mg, 1.0 mmol), aluminum foil (54 mg, 2.0 mmol), H_2O (90 µL, 5.0 mmol), and D_2O (91 µL, 5.0 mmol) were added to the 10 mL screw-capped stainless-steel vessel, along with one stainless steel ball (ø = 1.5 cm). The vessel was placed in the mixer mill, and milled at 30 Hz for 60min within a thermostat oven at 30 °C. At the end of the reaction, ethyl acetate (4 mL) was added into the vessel and grinding for another 10 - 20 seconds at 30 Hz, which was then filtered. Deuterium incorporation was 0.19 D_{MS} determined by GC-MS.

c) Radical inhibitory experiment

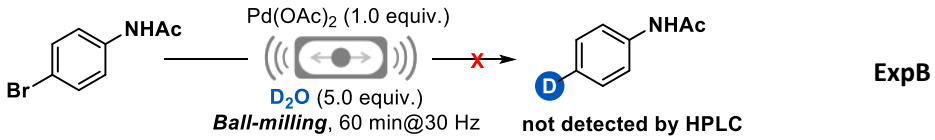
Due to the potential single electron transformation from zero-valent metal to carbon-halogen bond, we used tempo, a radical scavenger, to suppress the potential radical intermediate. However, the addition of tempo didn't inhibit the transformation (**ExpA**). Thus, the reaction may not undergo a radical mechanism via SET (Figure S2A).



Experimental Procedure of ExpA: A mixture of 4-bromoacetanilide (214 mg, 1.0 mmol), aluminum foil (54 mg, 2.0 mmol), $Pd(OAc)_2$ (11.2 mg, 5 mol %), 2,2,6,6-Tetramethylpiperidine 1-oxyl (**Tempo,** 157 mg, 1.0 mmol), and D_2O (182 µL, 10 mmol) were added to the 10 mL screw-capped stainless steel vessel, along with one stainless steel ball (ø = 1.5 cm). The vessel was placed in the mixer mill, and milled at 30 Hz for 60 min within a thermostat oven at 30 °C. At the end of the reaction, ethyl acetate (4 mL) was added into the vessel and grinding for another 10 - 20 seconds at 30 Hz, which was then filtered. The filtrate was dried over sodium sulfate and concentrated in vacuo to give a residue, which was purified by flash column chromatography on silica gel (eluents: n-hexane/ethyl acetate = 1/1) to give the desired product 130.7 mg (96%) as white solid.

d) Stoichiometric protonolysis experiment

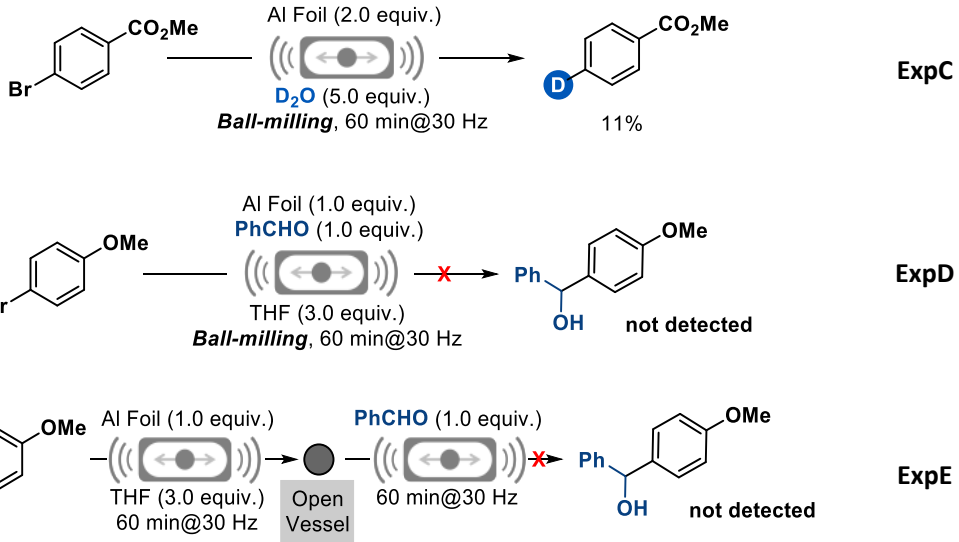
The debromination may furnished by a protonolysis from aryl-palladium species, where the reaction usually occurred under an acidic condition. However, the neutral environment of this reaction failed to finish the process (**ExpB**).



Experimental Procedure of ExpB: A mixture of 4-bromoacetanilide (43.4 mg, 0.2 mmol), $Pd(OAc)_2$ (45.0 mg, 0.2 mmol), $NaHCO_3$ (17.4 mg, 0.2 mmol), and D_2O (37 μL, 2.0 mmol) were added to the 10 mL screw-capped stainless steel vessel, along with one stainless steel ball (ø = 1.5 cm). The vessel was placed in the mixer mill, and milled at 30 Hz for 60min within a thermostat oven at 30 °C. At the end of the reaction, ethyl acetate (4 mL) was added into the vessel and grinding for another 10 - 20 seconds at 30 Hz, which was then filtered. No product was detected by HPLC.

e) Verification of involvement of organoaluminum species

We consider the reaction may be conducted by a mechanochemical induced Grignard-type transformation, where an organoaluminum species was generated during the mechanical grinding. Thus, we attempted the possibility to drive the reaction without catalyst. Despite a low yield of 11% was observed in **ExpC**, the extremely poor progression didn't match the reaction established, and the small degree of transformation may be catalyzed by trace amount of Pd in grinding vessel and ball. Thus, we turn to use nucleophilic addition to evaluate the hypothesis. Two procedures were employed including one-step Barbier-type procedure (**ExpD**) and a two-step one-pot protocol (**ExpE**) developed by Ito recently.[3] However, none of those reactions afforded detectable product, indicating the organoaluminum species may not involved in this deutero-dehalogenation protocol.



Experimental Procedure of ExpC: A mixture of Methyl 4-bromobenzoate (215 mg, 1.0 mmol), aluminum foil (55 mg, 2.0 mmol) and D_2O (95 μL, 5.0 mmol) were added to the 10 mL screw-capped stainless steel vessel, along with one

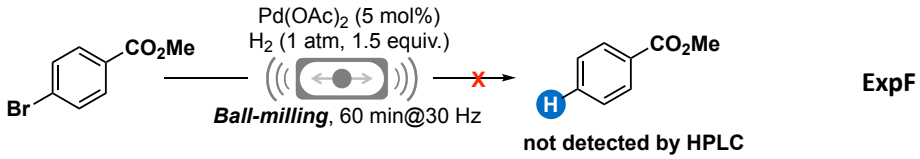
stainless steel balls (ø = 1.5 cm). The vessel was placed in the mixer mill, and milled at 30 Hz for 60 min within a thermostat oven at 30 °C. At the end of the reaction, ethyl acetate (4 mL) was added into the vessel and grinding for another 10 - 20 seconds at 30 Hz, which was then filtered. And only an 11% yield was determined by HPLC.

Experimental Procedure of ExpD: A mixture of 4-bromo-anisole (187 mg, 1.0 mmol), benzaldehyde (106 mg, 1.0 mmol), aluminum foil (27 mg, 1.0 mmol) and THF (110 µL, 3.0 mmol) were added to the 10 mL screw-capped stainless steel vessel, along with one stainless steel ball (ø = 1.5 cm). The vessel was placed in the mixer mill, and milled at 30 Hz for 60min within a thermostat oven at 30 °C. At the end of the reaction, H_2O (0.2 mL) and ethyl acetate (4 mL) were added into the vessel and grinding for another 10 - 20 seconds at 30 Hz, which was then filtered. No product was detected by HPLC.

Experimental Procedure of ExpE: A mixture of 4-bromo-anisole (187 mg, 1.0 mmol), aluminum foil (27 mg, 1.0 mmol) and THF (110 µL, 3.0 mmol) were added to the 10 mL screw-capped stainless steel vessel, along with one stainless steel ball (ø = 1.5 cm). The vessel was placed in the mixer mill, and milled at 30 Hz for 60min within a thermostat oven at 30 °C. After that, benzaldehyde (106 mg, 1.0 mmol) was added and reacted for 60 min again. At the end of the reaction, H_2O (0.2 mL) and ethyl acetate (4 mL) were added into the vessel and grinding for another 10 - 20 seconds at 30 Hz, which was then filtered. No product was detected by HPLC.

f) Hydrogen gas mediated dehalogenation

In some cases, we observe a phenomenon of gas leaking during the grinding course or vessel opening, which suggested the existence of hydrogen or deuterium gas in the reaction. Thus, a hydrogen or deuterium gas mediated dehalogenation was a plausible pathway. However, the **ExpF** failed to render any signal of reaction, indicating the gas may be a side-product of unmatched reaction rate. However, by adding aluminum foil (1.0 equiv.) into the mixture, the product could be observed with an elevated yield of 12%. The H_2 gas reaction with Pd/C as catalyst rendered a 16% yield after 1-hour grinding, however the standard condition at same scale afforded a much higher yield of 85%. The results were summarized in Figure 2B.



*Experimental Procedure of **ExpF:*** Methyl 4-bromobenzoate (53.8 mg, 0.25 mmol) and $Pd(OAc)_2$ (2.8 mg, 5 mol %) were added to the 10 mL screw-capped stainless steel vessel, along with one stainless steel ball (ø = 1.5 cm). The vessel was closed loosely, and was put in a glove-bag, which was evacuated and refilled with H_2 three times. For this 10 mL vessel, the calculated amount of H_2 gas under 1 atm should be 0.37 mmol. Then, the vessel was screwed tightly, and placed in the mixer mill, which was milled at 30 Hz for 60min within a thermostat oven at 30 °C. At the end of the reaction, ethyl acetate (4 mL) was added into the vessel and grinding for another 10 - 20 seconds at 30 Hz, which was then filtered. No product was detected by HPLC.

5. Characterization of deuterated compounds

1) Deutero-dehalogenation of aromatic bromides (Ar-Br)

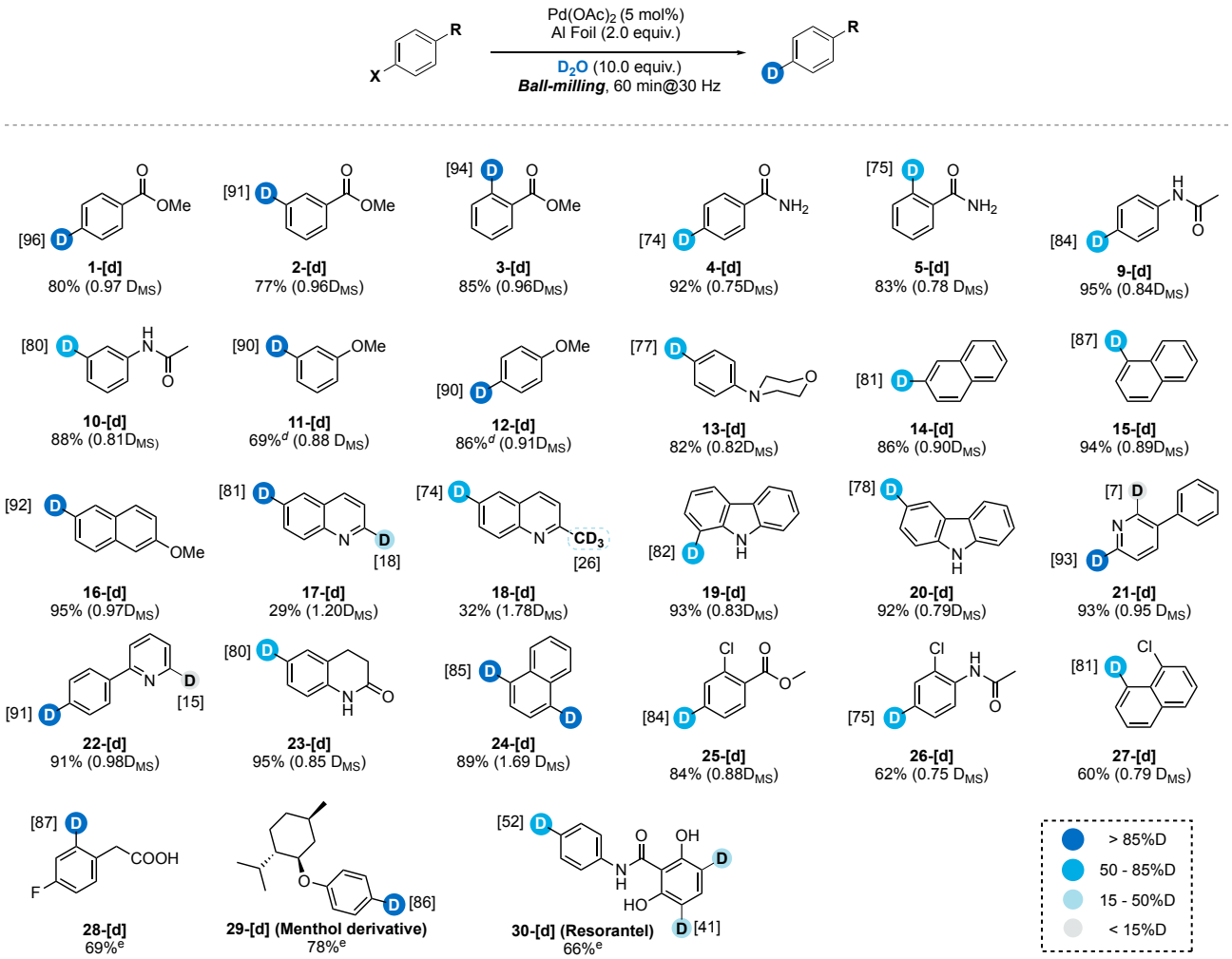


Figure S3 List of deuterated compounds from aryl bromides.

Methyl benzoate-4-d_1 (**1-[d]**).[6] General procedure to afford **1-[d]** as colorless liquid (110.2 mg, 80%) with D-incorporation 96% for 4-position by ^{1}H NMR and 0.97D_{MS} by GC-MS; R_f 0.30 (Petroleum ether/EtOAc = 40/1); **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.17 – 7.90 (m, 2H), 7.58 – 7.53 (m, 0.04H, **Labeled**), 7.44 (dt, J = 7.4, 1.0 Hz, 2H), 3.92 (s, 3H); **^{13}C NMR** (101 MHz, $CDCl_3$) δ 167.27, 135.36 – 124.09 (m), 52.24; **MS (EI)** 136.2 (4.37%), 137.1 (43.54%), 138.1 (3.94%).

Methyl benzoate-3-d_1 (**2-[d]**). [6] General procedure to afford **2-*[d]*** as colorless liquid (105.5 mg, 77%) with D-incorporation 91% for 3-position by ^{1}H NMR and 0.96 D_{MS} by GC-MS; R_f = 0.30 (Petroleum ether/EtOAc = 40/1); **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.12 – 7.99 (m, 2H), 7.56 (dp, J = 7.6, 1.3 Hz, 1H), 7.44 (dd, J = 8.3, 7.5 Hz, 1.09H, **Labeled**), 3.92 (s, 3H); **MS (EI)** 136.1 (5.33%), 137.1 (38.70%), 138.1 (3.66%).

Methyl benzoate-2-d_1 (**3-[d]**).[6] General procedure to afford **3-[d]** as colorless liquid (116.2 mg, 85%) with D-incorporation 94% for 2-position by ^{1}H NMR and 0.96 D_{MS} by GC-MS; R_f 0.30 (Petroleum ether/EtOAc = 40/1);

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.08 – 8.01 (m, 1.06H, **Labeled**), 7.56 (td, J = 7.5, 1.3 Hz, 1H), 7.49 – 7.40 (m, 2H), 3.92 (s, 3H); **MS (EI)** 136.1 (4.46%), 137.1 (39.26%), 138.1 (3.88%).

Benzamide-4-d_1 (**4-[d]**).[6] General procedure to afford **4-[d]** as white solid (112.6 mg, 92%) with D-incorporation 74% for 4-position by ^{1}H NMR and 0.75 D_{MS} by GC-MS; R_f 0.50 (EtOAc); **^{1}H NMR** (400 MHz, DMSO-d_6) δ 7.96 (s, 1H), 7.87 (d, J = 7.7 Hz, 2H), 7.45 (dd, J = 7.8, 3.8 Hz, 2.26H, **Labeled**), 7.35 (s, 1H); **MS (EI)** 121.1 (29.80%), 122.1 (82.26%), 123.1 (8.24%).

Benzamide-2-d_1 (**5-[d]**).[6] General procedure to afford **5-[d]** as white solid (101.7 mg, 83%) with D-incorporation 75% for 2-position by ^{1}H NMR and 0.78 D_{MS} by GC-MS; R_f 0.50 (EtOAc); **^{1}H NMR** (400 MHz, DMSO-d_6) δ 7.97 (s, 1H), 7.88 (d, J = 7.7 Hz, 1.25H, **Labeled**), 7.58 – 7.41 (m, 3H), 7.37 (s, 1H); **MS (EI)** 121.1 (23.3.%), 122.1 (79.94%), 123.1 (7.54%).

N-(Phenyl-4-d)acetamide (**9-[d]**).[7] General procedure to afford **9-[d]** as white solid (129.6 mg, 95%) with D-incorporation 84% for 4-position by ^{1}H NMR and 0.84 D_{MS} by GC-MS; R_f 0.75 (EtOAc); **^{1}H NMR** (400 MHz, $CDCl_3$ with a drop D_2O) δ 7.50 (d, *J* = 8.0 Hz, 2H), 7.30 (d, *J* = 7.9 Hz, 2H), 7.09 (t, *J* = 7.4 Hz, 0.16H, **Labeled**), 2.18 – 2.14 (m, 3H); **MS (EI)** 135.1 (4.24%), 136.1 (31.66%), 137.1 (3.19%). **For gram-scale examination**, general procedure with *N*-(3-bromophenyl)acetamide (1.067 g, 5 mmol) to afford **9-[d]-scale** as white solid (661.9 mg, 97%) with D-incorporation 83% for 4-position by ^{1}H NMR and 0.87 D_{MS} by GC-MS; R_f 0.75 (EtOAc); **^{1}H NMR** (400 MHz, $CDCl_3$ with a drop D_2O) δ 7.50 (d, *J* = 8.0 Hz, 2H), 7.30 (d, *J* = 7.9 Hz, 2H), 7.09 (t, *J* = 7.4 Hz, 0.17H, **Labeled**), 2.16 (s, 2H); **MS (EI)** 135.1 (4.24%), 136.1 (31.66%), 137.1 (3.19%).

N-(Phenyl-3-d)acetamide (**10-[d]**).[7] General procedure to afford **10-[d]** as white solid (119.8 mg, 88%) with D-incorporation 80% for 3-position by ^{1}H NMR and 0.81 D_{MS} by GC-MS; R_f 0.75 (EtOAc); **^{1}H NMR** (400 MHz, $CDCl_3$ + D_2O) δ 7.50 (d, J = 5.5 Hz, 2H), 7.30 (t, J = 7.9 Hz, 1.20H, **Labeled**), 7.09 (d, J = 7.4 Hz, 1H), 2.16 (s, 3H); **MS (EI)** 135.1 (7.33%), 136.1 (30.95%), 137.1 (3.16%).

Anisole-3-d_1 (**11-[d]**).[8] General procedure to afford **11-[d]** as colorless liquid (69%, yield determined by HPLC) with D-incorporation 90% for 3-position by ^{1}H NMR and 0.88 D_{MS} by GC-MS; R_f 0.50 (Petroleum ether); **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.30 (dd, J = 9.0, 7.3 Hz, 1.10H, **Labeled**), 6.99 – 6.88 (m, 3H), 3.82 (s, 3H); **MS (EI)** 108.1 (7.83%), 109.1 (64.09%), 110.1 (5.03%).

Anisole-4-d_1 (**12-[d]**).[9] General procedure to afford **12-[d]** as colorless liquid (86%, yield determined by HPLC) with D-incorporation 90% for 4-position by ^{1}H NMR and 0.91 D_{MS} by GC-MS; R_f 0.50 (Petroleum ether); **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.30 (dq, *J* = 7.6, 1.0 Hz, 2H), 6.99 – 6.95 (m, 0.10H, **Labeled**), 6.95 – 6.89 (m, 2H), 3.82 (s, 3H); **MS (EI)** 108.1 (11.38%), 109.1 (100.00%), 110.1 (8.31%).

4-(Phenyl-4-d)morpholine (**13-[d]**).[10] General procedure to afford **13-[d]** as white solid (135.1 mg, 82%) with D-incorporation 77% for phenyl-4-position by ^{1}H NMR and 0.82 D_{MS} by GC-MS; R_f 0.80 (Petroleum ether/EtOAc = 1/1); **^{1}H NMR** (400 MHz, DMSO-d_6) δ 7.40 – 7.12 (m, 2H), 6.93 (d, *J* = 8.5 Hz, 2H), 6.80 (t, *J* = 7.3 Hz, 0.23H, **Labeled**), 4.02 – 3.53 (m, 5H), 3.08 (dd, *J* = 5.8, 3.8 Hz, 5H); **MS (EI)** 163.2 (36.17%), 164.2 (85.06%), 165.2 (10.11%).

Naphthalene-2-d_1 (**14-[d]**).[11] General procedure to afford **14-[d]** as white solid (111.3 mg, 86%) with D-incorporation 81% for 2-position by ^{1}H NMR and 0.90 D_{MS} by GC-MS; R_f 0.65 (Petroleum ether); **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.86 (dd, J = 5.8, 3.2 Hz, 4H), 7.56 – 7.44 (m, 3.19H, **Labeled**); **MS (EI)** 126.1, 127.1 (8.25%), 128.1 (26.90%), 129.1 (100.00%), 130.1 (10.56%).

Naphthalene-1-d_1 (**15-[d]**).[10] General procedure to afford **15-[d]** as white solid (121.1 mg, 94%) with D-incorporation 87% for 1-position by ^{1}H NMR and 0.89 D_{MS} by GC-MS; R_f 0.65 (Petroleum ether); **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.86 (dd, J = 5.9, 3.5 Hz, 3.13H, **Labeled**), 7.58 – 7.39 (m, 4H); **MS (EI)** 127.1 (7.6%), 128.1 (19.75%), 129.1 (100.00%), 130.1 (11.00%).

2-Methoxynaphthalene-6-d_1 (**16-[d]**).[10] General procedure to afford **16-[d]** as white solid (151.6 mg, 95%) with D-incorporation 92% for 6-position by ^{1}H NMR and 0.97 D_{MS} by GC-MS; R_f 0.30 (Petroleum ether); **^{1}H NMR** (400 MHz, DMSO-d_6) δ 7.85 – 7.75 (m, 3H), 7.49 – 7.42 (m, 1H), 7.38 – 7.29 (m, 1.08H, **Labeled**), 7.16 (dd, J = 8.9, 2.6 Hz, 1H), 3.87 (s, 3H); **^{13}C NMR** (101 MHz, DMSO-d_6) δ 123.69 – 122.58 (m), 158.39 – 49.55 (m); **MS (EI)** 159.2 (100.00%), 160.2 (12.86%).

Quinoline-6-d_1 (**17-[d]**).[12] General procedure to afford **17-[d]** as light yellow liquid (37.2 mg, 29%) with D-incorporation 81% for 6-position and 18% for 2-position by ^{1}H NMR and 1.20 D_{MS} by GC-MS; R_f 0.35 (Petroleum ether/EtOAc = 8/1); **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.93 (dd, *J* = 4.3, 1.8 Hz, 0.82H, **Labeled**), 8.19 (d, *J* = 8.3 Hz, 1H), 8.14 (d, *J* = 8.1 Hz, 1H), 7.84 (s, 1H), 7.77 – 7.70 (m, 1H), 7.60 – 7.53 (ddd, *J* = 8.2, 6.8, 1.2 Hz, 0.19H, **Labeled**), 7.45 – 7.39 (m, 1H); **MS (EI)** 129.2 (34.65%), 130.2 (100%), 131.2 (43.11%), 132.1 (6.66%).

2-Methylquinoline-6-d_1 (**18-[d]**).[13] General procedure to afford **18-[d]** as colorless liquid (45.9 mg, 32%) with D-incorporation 74% for 6-position and 26% for methyl by ^{1}H NMR and 1.78 D_{MS} by GC-MS; R_f 0.50 (Petroleum ether/EtOAc = 1/1); **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.03 (t, *J* = 8.4 Hz, 2H), 7.80 – 7.73 (m, 1H), 7.72 – 7.63 (m, 1H), 7.48 (ddd, *J* = 8.1, 6.8, 1.2 Hz, 0.26H, **Labeled**), 7.31 – 7.25 (m, 1H), 2.78 – 2.68 (m, 2.22H, **Labeled**); **MS (EI)** 142.1 (1.34%), 142.3 (8.11%), 143.2 (43.25%), 145.2 (91.39%), 146.2 (45.06%), 147.2 (20.19%) 148.2 (11.99%), 149.2 (5.48%).

9H-Carbazole-1-d_1 (**19-[d]**).[14] General procedure to afford **19-[d]** as white solid (155.6 mg, 93%) with D-incorporation 82% for 1-position by ^{1}H NMR and 0.83 D_{MS} by GC-MS; R_f 0.15 (Petroleum ether/EtOAc = 20/1); **^{1}H NMR** (400 MHz, DMSO-d_6) δ 11.23 (s, 1H), 8.10 (d, J = 7.8 Hz, 2H), 7.68 – 7.30 (m, 3.18H, **Labeled**), 7.15 (t, J = 7.5 Hz, 2H); **MS (EI)** 164.2 (1.31%), 165.2 (2.67%), 166.2 (8.83%), 167.2 (55.04%), 168.2 (100.00%), 169.2 (22.92%), 170.2 (1.85%).

9H-Carbazole-3-d_1 (**20-[d]**).[14] General procedure to afford **20-[d]** as white solid (154.5 mg, 92%) with D-incorporation 78% for 1-position by ^{1}H NMR and 0.79 D_{MS} by GC-MS; R_f 0.15 (Petroleum ether/EtOAc = 20/1); **^{1}H NMR** (400 MHz, DMSO-d_6) δ 11.23 (s, 1H), 8.14 – 8.07 (m, 2H), 7.63 – 7.26 (m, 4H), 7.15 (t, J = 7.4 Hz, 1.22H, **Labeled**); **MS (EI)** 164.2 (1.25%), 165.1 (2.81%), 166.2 (7.96%), 167.2 (51.23%), 168.2 (100.00%), 169.2 (19.43%), 170.2 (1.32%).

3-Phenylpyridine-6-d_1 (**21-[d]**).[15] General procedure to afford **21-[d]** as colorless liquid (150.4 mg, 96%) with

D-incorporation 93% for 6-position and 7% for 2-position by ^{1}H NMR and 0.95 D_{MS} by GC-MS; R_f 0.30 (Petroleum ether/EtOAc = 6/1); **^{1}H NMR** (400 MHz, DMSO-d_6) δ 8.89 (dd, *J* = 2.5, 0.9 Hz, 0.93H, **Labeled**), 8.58 (dd, *J* = 4.8, 1.6 Hz, 0.07H, **Labeled**), 8.07 (dd, *J* = 7.9, 2.4 Hz, 1H), 7.76 – 7.69 (m, 2H), 7.55 – 7.46 (m, 3H), 7.46 – 7.39 (m, 1H); MS **(EI)** 153.2 (1.29%), 154.2 (8.62%), 155.2 (59.64%), 156.2 (100.00%), 157.2 (14.58%) 158.2 (1.22%).

2-(Phenyl-4-d)pyridine (**22-[d]**).[16] General procedure to afford **22-[d]** as colorless liquid (141.6 mg, 91%) with D-incorporation 91% for phenyl-4-position and 15% for 2-position by ^{1}H NMR and 0.98 D_{MS} by GC-MS; R_f 0.30 (Petroleum ether/EtOAc = 8/1); **^{1}H NMR** (400 MHz, DMSO-d_6) δ 8.67 (ddd, *J* = 4.8, 1.8, 0.9 Hz, 0.85H, **Labeled**), 8.13 – 8.04 (m, 2H), 7.96 (dt, *J* = 8.0, 1.1 Hz, 1H), 7.88 (td, *J* = 7.7, 1.8 Hz, 1H), 7.52 – 7.47 (m, 2H), 7.46 – 7.43 (m, 0.09H, **Labeled**), 7.35 (ddd, *J* = 7.4, 4.8, 1.2 Hz, 1H); **MS (EI)** 152.1 (0.54%) 153.2 (1.81%), 154.2 (14.14%), 155.2 (74.81%), 156.2 (100.00%), 157.1 (24.02%), 158.2 (2.58%).

3,4-Dihydroquinolin-2 (1H)-one-6-d_1 (**23-[d]**).[17] General procedure to afford **23-[d]** as white solid (140.3 mg, 95%) with D-incorporation 80% for 6-position by ^{1}H NMR and 0.85 D_{MS} by GC-MS; R_f 0.75 (EtOAc); **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.93 (s, 1H), 7.17 (d, *J* = 9.2 Hz, 2H), 6.99 (t, *J* = 7.5 Hz, 0.20H, **Labeled**), 6.83 (d, *J* = 7.8 Hz, 1H), 2.97 (t, *J* = 7.6 Hz, 2H), 2.65 (dd, *J* = 8.5, 6.6 Hz, 2H); **MS (EI)** 146.2 (1.19%), 147.1 (25.17%), 148.1 (100.00%), 149.1 (14.30%), 150.2 (1.44%).

Naphthalene-1,4-d_2 (**24-[d]-2Br**).[11] General procedure to afford **24-[d]-2Br** as white solid (58.1 mg, 89%, 0.5 mmol substrate, 4.0 eq. Al, 10 mol % $Pd(OAc)_2$ and 20.0 eq. D_2O was used) with D-incorporation 85% for l,4-positions by ^{1}H NMR and 1.69 D_{MS} by GC-MS; R_f 0.65 (Petroleum ether); **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.86 (dd, J = 6.2, 3.3 Hz, 2.31H, **Labeled**), 7.55 – 7.43 (m, 4H); **MS (EI)** 126.1 (1.09%), 127.1 (4.61%), 128.1 (13.17), 129.1 (43.01), 130.1 (100.00%), 131.1 (11.09%) 132.1 (0.72%).

Methyl 2-chlorobenzoate-4-d_1 (**25-[d]**).[18] General procedure to afford **25-[d]** as colorless liquid (71.9 mg, 84%) with D-incorporation 84% for 4-position by ^{1}H NMR and 0.88 D_{MS} by GC-MS; R_f 0.35 (Petroleum ether/EtOAc = 40/1); **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.82 (d, J = 7.8 Hz, 1H), 7.51 – 7.40 (m, 1.16H, **Labeled**), 7.31 (dd, J = 7.9, 1.1 Hz, 1H), 3.94 (s, 3H); **MS (EI)** 170.0 (4.36%), 171.0 (29.98%), 172.0 (3.05%), 173.0 (9.45%), 173.1 (0.87%).

N-(2-Chlorophenyl-4-d)acetamide (**26-[d]**).[19] General procedure to afford **26-[d]** as white solid (53.0 mg, 62%, 0.5 mmol substrate was used) with D-incorporation 75% for 4-position by ^{1}H NMR and 0.75 D_{MS} by GC-MS; R_f 0.40 (Petroleum ether/EtOAc = 2/1); **^{1}H NMR** (400 MHz, CD_3OD) δ 7.73 (d, *J* = 8.1 Hz, 1H), 7.44 (q, *J* = 2.7 Hz, 1H), 7.28 (dd, *J* = 7.2, 2.8 Hz, 1H), 7.17 (td, *J* = 7.7, 1.6 Hz, 0.25H, **Labeled**), 2.18 (s, 3H); **MS (EI)** 169.1 (4.71%), 170.1 (14.57%), 171.1 (2.89%).

1-Chloronaphthalene-8-d_1 (**27-[d]**).[20] General procedure to afford **27-[d]** as colorless liquid (48.7 mg, 60%, 0.5 mmol substrate was used) with D-incorporation 81% for 8-position by ^{1}H NMR and 0.79 D_{MS} by GC-MS; R_f 0.70 (Petroleum ether); **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.27 (dd, *J* = 8.6, 1.1 Hz, 0.19H, **Labeled**), 7.86 (dd, *J* = 8.1, 1.4 Hz, 1H), 7.76 (dd, *J* = 8.2, 1.1 Hz, 1H), 7.65 – 7.49 (m, 3H), 7.38 (dd, *J* = 8.2, 7.4 Hz, 1H); **MS (EI)** 162.1 (24.33%), 163.1 (100.00%), 164.1 (18.69%).

2-(4-Fluorophenyl-2-d)acetic acid (**28-[d]**).[21] General procedure to afford **28-[d]** as white solid (105.3 mg, 69%)

with D-incorporation 87% for 2-position by ^{1}H NMR; R_f 0.35 (Petroleum ether/EtOAc = 4/1); **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.34 – 7.22 (m, 1.13H, **Labeled**), 7.10 – 6.97 (m, 2H), 3.66 (s, 2H).

1-(((1R,2S,5R)-2-Isopropyl-5-methylcyclohexyl)oxy)benzene-4-d_1 (**29-[d]**).[11] General procedure to afford **29-[d]** as white solid (90.7 mg, 78%, 0.5 mmol substrate was used) with D-incorporation 86% for 4-position by ^{1}H NMR; R_f 0.40 (Petroleum ether); **^{1}H NMR** (400 MHz, DMSO-d_6) δ 7.29 – 7.18 (m, 2H), 6.95 – 6.90 (m, 2H), 6.90 – 6.85 (m, 0.09H, **Labeled**), 4.10 (td, *J* = 10.5, 4.1 Hz, 1H), 2.17 – 2.01 (m, 2H), 1.66 (tq, *J* = 13.3, 3.3 Hz, 2H), 1.59 – 1.38 (m, 2H), 1.09 (qd, *J* = 13.3, 3.8 Hz, 1H), 0.98 – 0.81 (m, 8H), 0.73 (d, *J* = 6.9 Hz, 3H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ 158.53, 129.50, 120.41 (d, J = 26.8 Hz), 116.00, 77.59, 52.73 – 13.22 (m); **MS (EI)** 232.2 (2.19%), 233.2 (16.29%), 234.2 (2.90%).

2,6-Dihydroxy-N-(phenyl-4-d)benzamide (**30-[d]**).[22] General procedure to afford **30-[d]** as white solid (75.7 mg, 66%) with D-incorporation 52% for 4-position and 41% for hydroxyl ortho position by ^{1}H NMR; R_f 0.40 (Petroleum ether/EtOAc = 4/1); **^{1}H NMR** (400 MHz, DMSO-d_6) δ 12.25 (s, 2H), 10.74 (s, 1H), 7.65 (d, *J* = 8.3 Hz, 2H), 7.38 (dt, *J* = 8.5, 3.7 Hz, 2H), 7.29 – 7.10 (m, 1.48H, **Labeled**), 6.44 (d, *J* = 8.2 Hz, 1.18H, **Labeled**).

Corresponding NMR spectrum for the product from aryl bromides could be found in Figure S10 to S40.

2) Deutero-dehalogenation of aromatic iodides (Ar-I)

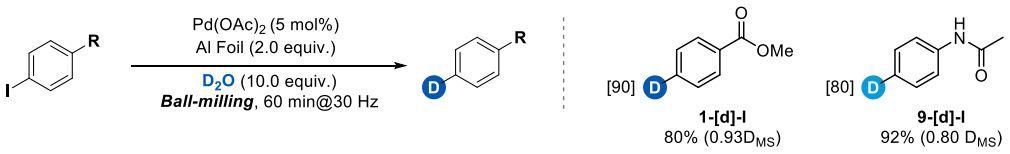


Figure S4 List of deuterated compounds from aryl iodides.

Methyl benzoate-4-d_1 (**1-[d]-I**).[6] General procedure to afford **1-[d]-I** as colorless liquid (109.8 mg, 80%) with D-incorporation 90% for 4-position by ^{1}H NMR and 0.93 D_{MS} by GC-MS; R_f = 0.30 (Petroleum ether/EtOAc = 40/1); **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.04 (d, J = 8.3 Hz, 2H), 7.58 – 7.53 (m, 0.10H, **Labeled**), 7.44 (m, 3H), 3.92 (s, 4H); **MS (EI)** 136.1 (6.33%), 137.1 (40.15%), 138.1 (3.91%).

N-(Phenyl-4-d)acetamide (**9-[d]-I**).[6] General procedure to afford **9-[d]-I** as white solid (125.0 mg, 92%) with D-incorporation 80% for 4-position by ^{1}H NMR and 0.80 D_{MS} by GC-MS; R_f 0.75 (EtOAc); **^{1}H NMR** (400 MHz, CD_3OD) δ 7.55 – 7.49 (m, 2H), 7.29 (t, *J* = 6.1 Hz, 2H), 7.12 – 7.04 (m, 0.20H, **Labeled**), 2.11 (s, 3H); **^{13}C NMR** (101 MHz, CD_3OD) δ 171.63, 139.88, 129.70 (d, J = 11.3 Hz), 125.99 – 123.62 (m), 121.19, 23.78; **MS (EI)** 135.1 (7.66%), 136.1 (34.14%), 137.1 (3.21%).

Corresponding NMR spectrum for the product from aryl iodides could be found in Figure S41 to S43.

3) Deutero-dehalogenation of aromatic chlorides (Ar-Cl)

Methyl benzoate-4-d (**1-[d]-Cl**).[6] General procedure to afford **1-[d]-Cl** as colorless liquid (116.7 mg, 85%) with D-incorporation 91% for 4-position by ^{1}H NMR and 0.93 D_{MS} by GC-MS; R_f 0.30 (Petroleum ether/EtOAc = 40/1); **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.11 – 7.96 (m, 2H), 7.59 – 7.53 (m, 0.09H, **Labeled**), 7.47 – 7.39 (m, 2H), 3.92 (s,

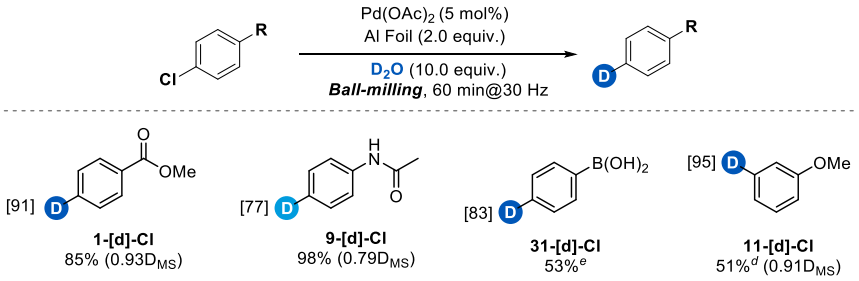


Figure S5 List of deuterated compounds from aryl chlorides.

3H); **MS (EI)** 136.1 (6.17%), 137.1 (39.95%), 138.1 (3.27%).

N-(Phenyl-4-d)acetamide (**9-[d]-Cl**).[6] General procedure to afford **9-[d]-Cl** as white solid (132.7 mg, 98%) with D-incorporation 77% for 4-position by ^{1}H NMR and 0.79 D_{MS} by GC-MS; R_f 0.75 (EtOAc); **^{1}H NMR** (400 MHz, CD_3OD) δ 7.57 – 7.49 (m, 2H), 7.28 (dd, *J* = 8.0, 3.7 Hz, 2H), 7.11 – 7.04 (m, 0.23H, **Labeled**), 2.11 (s, 3H); **MS (EI)** 135.1 (8.67%), 136.1 (30.79%), 137.1 (3.35%).

Anisole-3-d (**11-[d]-Cl**).[8] General procedure to afford **11-[d]-Cl** as colorless liquid (51%, yield determined by HPLC) with D-incorporation 95% for 3-position by ^{1}H NMR and 0.91 D_{MS} by GC-MS; R_f 0.50 (Petroleum ether); **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.30 (dd, J = 9.0, 7.3 Hz, 1.05H, **Labeled**), 7.00 – 6.87 (m, 3H), 3.82 (s, 3H); **MS (EI)** 108.1 (8.95%), 109.1 (90.10%), 110.1 (6.84%).

(Phenyl-4-d)boronic acid (**31-[d]-Cl**).{SCHELTER,2018) General procedure to afford **31-[d]-Cl** as white solid (65.6 mg, 53%) with D-incorporation 83% for 4-position by ^{1}H NMR; R_f 0.15 (Petroleum ether/EtOAc = 4/1); **^{1}H NMR** δ 7.89 (br., 2H), 7.85 – 7.74 (m, 2H), 7.44 – 7.26 (m, 2.17H, **Labeled**).

Corresponding NMR spectrum for the product from aryl chlorides could be found in Figure S44 to S47.

4) Deutero-dehalogenation of aromatic fluorosulfates (Ar-OFs)

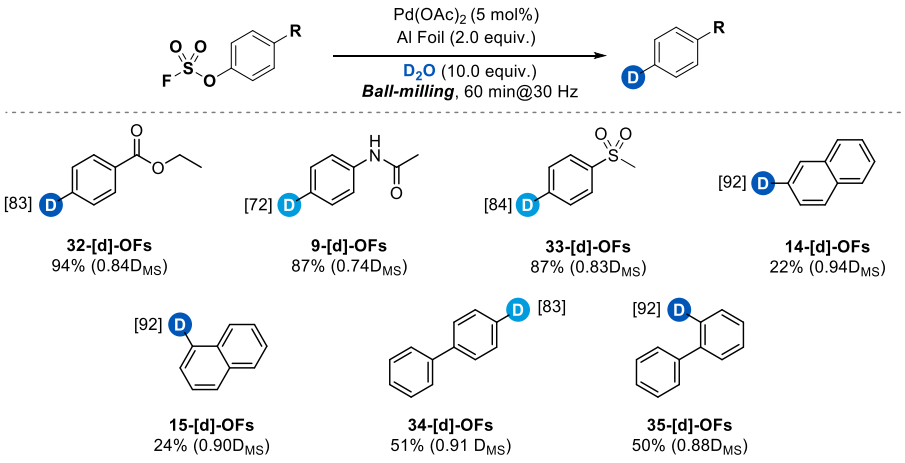


Figure S6 List of deuterated compounds from aryl fluorosulfates.

N-(Phenyl-4-d)acetamide (**9-[d]-OFs**).{MUTSUMI, 2011} General procedure to afford **9-[d]-OFs** as white solid

(117.8 mg, 87%) with D-incorporation 72% for 4-position by ^{1}H NMR and 0.74 D_{MS} by GC-MS; R_f 0.75 (EtOAc); **^{1}H NMR** (400 MHz, CD_3OD) δ 7.56 – 7.49 (m, 2H), 7.28 (dd, *J* = 8.3, 3.5 Hz, 2H), 7.08 (tt, *J* = 7.3, 1.2 Hz, 0.28H, **Labeled**), 2.12 (s, 3H); **MS (EI)** 135.1 (11.56%), 136.1 (31.67%), 137.1 (3.46%).

Naphthalene-2-d (**14-[d]-OFs**).[7] General procedure to afford **14-[d]-OFs** as white solid (28.1 mg, 22%) with D-incorporation 92% for 2-position by ^{1}H NMR and 0.94 D_{MS} by GC-MS; R_f 0.65 (Petroleum ether); **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.87 (dd, J = 5.8, 3.2 Hz, 4H), 7.60 – 7.44 (m, 3.08H, **Labeled**); **MS (EI)** 127.1 (7.06%), 128.1 (19.95%), 129.1 (100.00%), 130.1 (11.14%).

Naphthalene-1-d (**15-[d]-OFs**).[23] General procedure to afford **15-[d]-OFs** as white solid (30.5 mg, 24%) with D-incorporation 92% for 1-position by ^{1}H NMR and 0.90 D_{MS} by GC-MS; R_f 0.65 (Petroleum ether); **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.88 – 7.82 (m, 3.08H, **Labeled**), 7.55 – 7.43 (m, 4H); **MS (EI)** 127.1 (7.58%), 128.1 (20.16%), 129.1 (100.00%), 130.1 (11.36%).

Ethyl benzoate-4-d (**32-[d]-OFs**).[11] General procedure to afford **32-[d]-OFs** as colorless liquid (141.2 mg, 94%) with D-incorporation 83% for 4-position by ^{1}H NMR and 0.84 D_{MS} by GC-MS; R_f 0.45 (Petroleum ether/EtOAc = 20/1); **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.09 – 8.01 (m, 2H), 7.58 – 7.52 (m, 0.17H, **Labeled**), 7.44 (d, *J* = 7.9 Hz, 2H), 4.38 (q, *J* = 7.1 Hz, 2H), 1.40 (t, *J* = 7.1 Hz, 3H); **MS (EI)** 149.1 (0.69%), 150.1 (6.74%), 151.1 (23.14%), 152.1 (2.40%).

1-(Methylsulfonyl)benzene-4-d (**33-[d]-OFs**).[10] General procedure to afford **33-[d]-OFs** as colorless liquid (68.2 mg, 87%, 0.5 mmol substrate was used) with D-incorporation 84% for 4-position by ^{1}H NMR and 0.83 D_{MS} by GC-MS; R_f 0.55 (Petroleum ether/EtOAc = 1/1); **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.01 – 7.91 (m, 2H), 7.70 – 7.63 (m, 0.16H, **Labeled**), 7.61 – 7.54 (m, 2H), 3.06 (s, 3H); **MS (EI)** 156.1 (6.73%), 157.1 (36.15%), 158.1 (3.58%), 159.1 (1.92%).

1,1'-Biphenyl-4-d (**34-[d]-OFs**).[10] General procedure to afford **34-[d]-OFs** as white solid (79.4 mg, 51%) with D-incorporation 83% for 4-position by ^{1}H NMR and 0.91 D_{MS} by GC-MS; R_f 0.40 (Petroleum ether); **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.70 – 7.56 (m, 4H), 7.52 – 7.43 (m, 4H), 7.42 – 7.34 (m, 1.17H, **Labeled**); **MS (EI)** 151.1 (3.32%), 152.1 (10.37%), 153.1 (25.71%), 154.1 (34.42%), 155.1 (78.89%), 156.1 (12.71%).

1,1'-Biphenyl-2-d (**35-[d]-OFs**).[16] General procedure to afford **35-[d]-OFs** as white solid (77.2 mg, 50%) with D-incorporation 92% for 2-position by ^{1}H NMR and 0.88 D_{MS} by GC-MS; R_f 0.40 (Petroleum ether); **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.67 – 7.58 (m, 3.08H, **Labeled**), 7.52 – 7.42 (m, 4H), 7.37 (td, *J* = 7.5, 1.2 Hz, 2H); **MS (EI)** 151.1 (1.06%), 152.1 (12.74%), 153.1 (29.36%), 154.1 (50.56%), 155.1 (100.00%), 156.1 (12.60%).

Corresponding NMR spectrum for the product from aryl fluorosulfates could be found in Figure S48 to S54.

5) Failed Cases for mechanochemical condition

Besides the succeeded cases reported above, we also notice the limitation of the protocol (Figure S7). Formyl, acetyl, as well as nitro groups were reduced during the grinding as mentioned in main text. It should be noted that the nitro reduction also required an Al/D_2O(H_2O) combination as hydrogen source, where direct used of H_2 gas and Pd/C could hardly promote the reduction under this mechanochemical condition. 2,4,6-tri-*tert*-Butylphenylbromide may be failed due to the steric hindrance, while the potential role of triphenylamine may also hamper the reaction as a ligand. The mechanochemical treatment of **36** didn't render any trace of product, however, the substrate could be transformed quantitively under the solution condition. We also found the reaction was failed in a series of sophisticated structures. For most cases, the failure was attributed to the presence of a bidentate ligand-type structure, leading to an inhibition of catalysis.

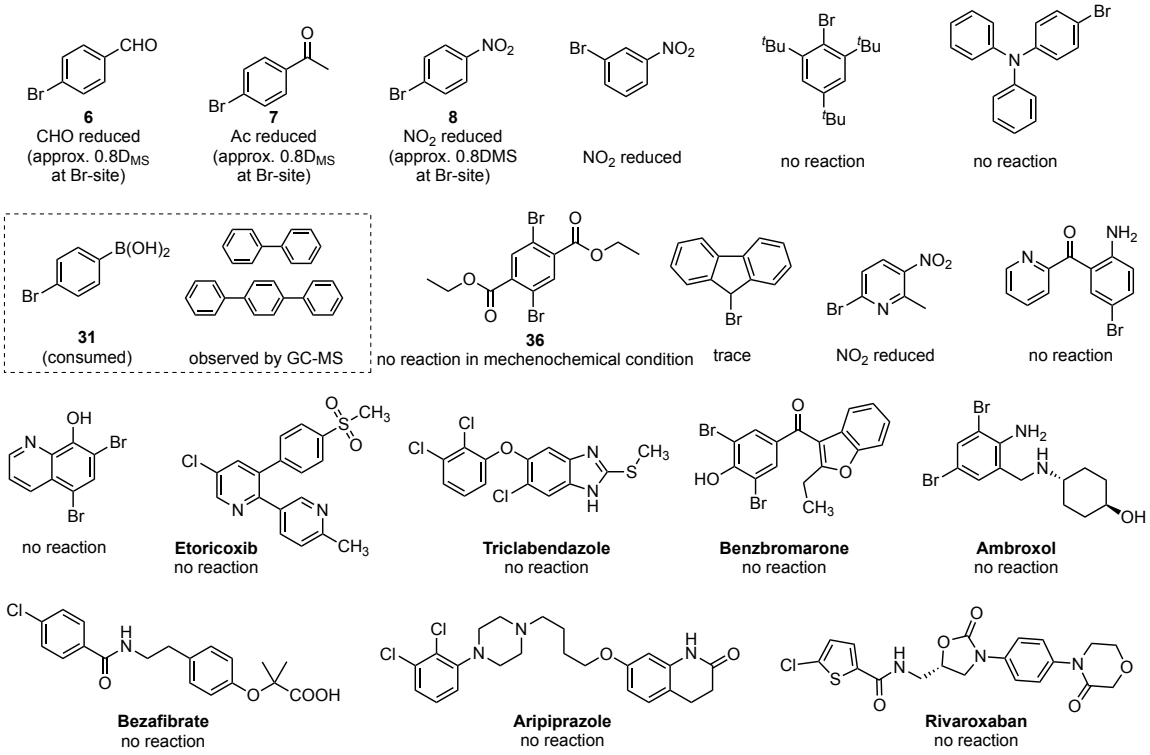


Figure S7 Failed cases for mechanochemical deuteron-dehalogenation.

6. Deutero-dehalogenation in solution environment

The solution reaction was firstly designed for routine comparison between mechanochemical condition and conventional solution reaction. However, the solution reaction appeared to render considerable results excessing the mechanochemical process. Thus, a preliminary investigation of substrate scope was conducted.

a) General procedure for solution reaction:

To a 10 mL reaction vessel, aromatic halide (1.0 equiv.), aluminum foil (2.0 equiv.), and $Pd(OAc)_2$ (5 mol %) were weighted. Then, the tube was sealed, evacuated, and refilled with N_2 for three times. Subsequently, THF (1.0 mL) and D_2O (1.0 mL) were added into the reaction via stringent. The mixture was then stirred at room temperature, and monitored by TLC. At the end of reaction, the mixture was extracted by ethyl acetate (3 ml◊3), dried over sodium sulfate and concentrated in vacuo to give a residue, which was purified by flash column chromatography on silica gel (eluents: n-hexane/ethyl acetate) to give the desired product.

b) Compound characterization of solution reactions

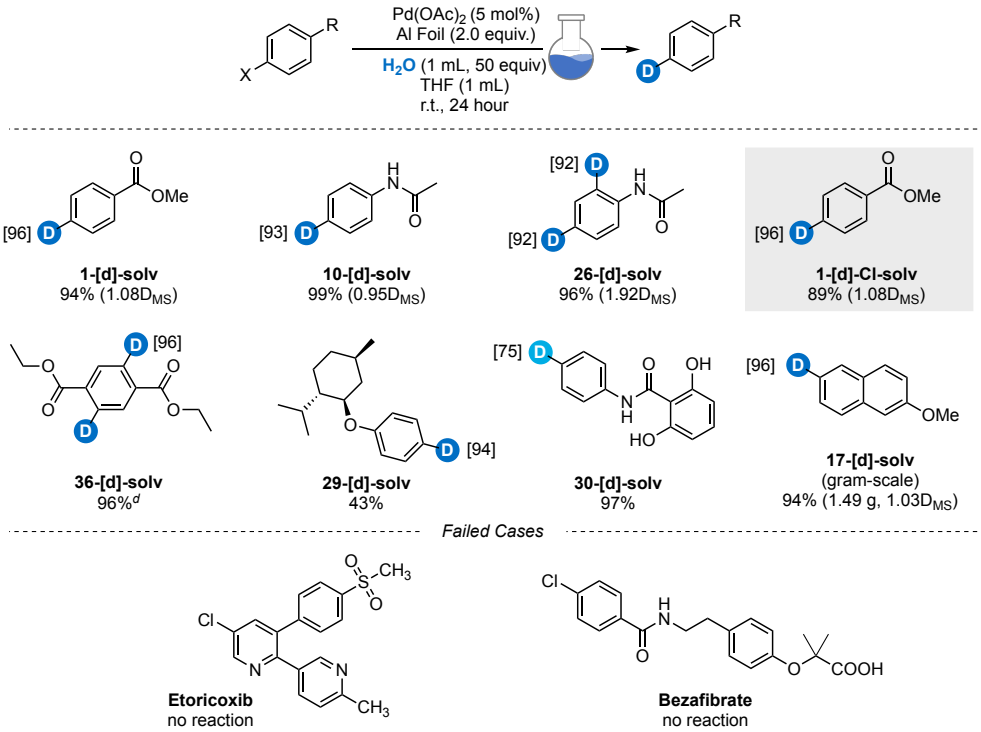


Figure S8 Substrates tested under solution condition.

Methyl benzoate-4-d (**1-[d]-solv**)**.** Solution procedure with methyl 4-bromo benzoate to afford **1-[d]-solv** as colorless liquid (127.6 mg, 94%) with D-incorporation 96% for 4-position by ^{1}H NMR and 1.08 D_{MS} by GC-MS; R_f 0.30 (Petroleum ether/EtOAc = 40/1); **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.09 – 8.00 (m, 1H), 7.58 – 7.52 (m, 0.04H, **Labeled**), 7.43 (dq, *J* = 7.5, 1.0 Hz, 1H), 3.92 (s, 2H); **MS (EI)** 136.1 (3.56%), 137.1 (35.29%), 138.1 (3.68%); Solution procedure with methyl 4-chloro benzoate to afford **1-[d]-Cl-solv** as colorless liquid (121.1 mg, 89%) with D-incorporation 96% for 4-position by ^{1}H NMR and 1.08 D_{MS} by GC-MS; R_f 0.30 (Petroleum ether/EtOAc = 40/1); **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.08 – 8.00 (m, 2H), 7.59 – 7.52 (m, 0.04H, **Labeled**), 7.44 (d, J = 7.8 Hz, 2H),

3.92 (s, 3H); **MS (EI)** 136.2 (4.18%), 137.1 (37.11%), 138.1 (3.45%).

N-(Phenyl-4-d)acetamide (**10-[d]-solv**). Solution procedure to afford **10-[d]-solv** as white solid (135.8 mg, 99%) with D-incorporation 93% for 4-position by ^{1}H NMR and 0.95 D_{MS} by GC-MS; R_f = 0.75 (EtOAc); **^{1}H NMR** (400 MHz, MeOD) δ 7.58 – 7.48 (m, 2H), 7.29 (d, *J* = 8.0 Hz, 2H), 7.07 (t, *J* = 7.5 Hz, 0.07H, **Labeled**), 2.11 (s, 3H); **MS (EI)** 135.2 (2.85%), 136.1 (28.37%), 137.2 (3.13%).

N-(Phenyl-2,4-d_2)acetamide (**26-[d]-solv**). Solution procedure with N-(2-Cl-4-Br-phenyl)acetamide to afford **26-[d]-solv** as white solid (129.4 mg, 96%, 4.0 eq. Al, 10 mol% $Pd(OAc)_2$ and 2mL D_2O was used) with D-incorporation 92% for 4-position and 92% for 2- position by ^{1}H NMR and 1.92 D_{MS} by GC-MS; R_f 0.75 (EtOAc); **^{1}H NMR** (400 MHz, MeOD) δ 7.52 (d, *J* = 8.5 Hz, 1.08H, **Labeled**), 7.32 – 7.25 (m, 2H), 7.07 (td, *J* = 7.4, 1.2 Hz, 0.08H, **Labeled**), 2.11 (s, 3H); **MS (EI)** 136.2 (4.14%), 137.15 (27.90%), 138.1 (4.69%).

Diethyl terephthalate-2,5-d_2 (**36-[d]-solv**). Solution procedure to afford **36-[d]-solv** as white solid (212.9 mg, 96%, 4.0 eq. Al, 10 mol % $Pd(OAc)_2$ and 2mL D_2O was used) with D-incorporation 96% for 2,5-positions by ^{1}H NMR; R_f 0.35 (Petroleum ether/EtOAc = 10/1); **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.09 (d, *J* = 1.0 Hz, 2H), 8.02 (s, 0.08H, **Labeled**), 4.40 (q, *J* = 7.1 Hz, 4H), 1.41 (t, *J* = 7.1 Hz, 6H).

1-(((1R,2S,5R)-2-Isopropyl-5-methylcyclohexyl)oxy)benzene-4-d (**29-[d]-solv**). Solution procedure to afford **28-[d]-solv** as white solid (100.4 mg, 43%) with D-incorporation 94% for 4-position by ^{1}H NMR; R_f 0.40 (Petroleum ether); **^{1}H NMR** (400 MHz, DMSO-d_6) δ 7.30 – 7.19 (m, 2H), 6.96 – 6.90 (m, 2H), 6.87 (d, *J* = 7.2 Hz, 0.06H, **Labeled**), 4.11 (td, *J* = 10.5, 4.1 Hz, 1H), 2.17 – 2.01 (m, 2H), 1.66 (tq, *J* = 13.3, 3.3 Hz, 2H), 1.59 – 1.38 (m, 2H), 1.09 (qd, *J* = 13.3, 3.8 Hz, 1H), 0.97 – 0.81 (m, 8H), 0.73 (d, *J* = 6.9 Hz, 3H).

2,6-Dihydroxy-N-(phenyl-4-d)benzamide (**30-[d]-solv**). Solution procedure to afford **30-[d]-solv** as white solid (221.3 mg, 97%) with D-incorporation 75% for 4-position by ^{1}H NMR; R_f 0.50 (Petroleum ether/EtOAc = 4/1); **^{1}H NMR** (400 MHz, DMSO-d_6) δ 12.27 (s, 2H), 10.75 (s, 1H), 7.66 (d, *J* = 8.0 Hz, 2H), 7.38 (d, *J* = 7.9 Hz, 2H), 7.26 – 7.12 (m, 1.25H, **Labeled**), 6.44 (d, *J* = 8.3 Hz, 2H).

2-Methoxynaphthalene-6-d (**17-[d]-solv**). Solution procedure to afford **17-[d]-solv** as white solid (1.49 g, 94%) with D-incorporation 96% for 6-position by ^{1}H NMR and 1.03 D_{MS} by GC-MS; R_f 0.30 (Petroleum ether); **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.81 – 7.74 (m, 3H), 7.46 (dd, *J* = 8.2, 1.2 Hz, 1H), 7.36 (ddd, *J* = 8.2, 6.8, 1.2 Hz, 0.06H, **Labeled**), 7.17 (d, *J* = 8.4 Hz, 2H), 3.94 (s, 3H); **MS (EI)** 159.1 (82.95%), 160.1 (11.14%), 161.15 (1.05%).

Corresponding NMR spectrum for the product of solution reactions could be found in Figure S54 to S61.

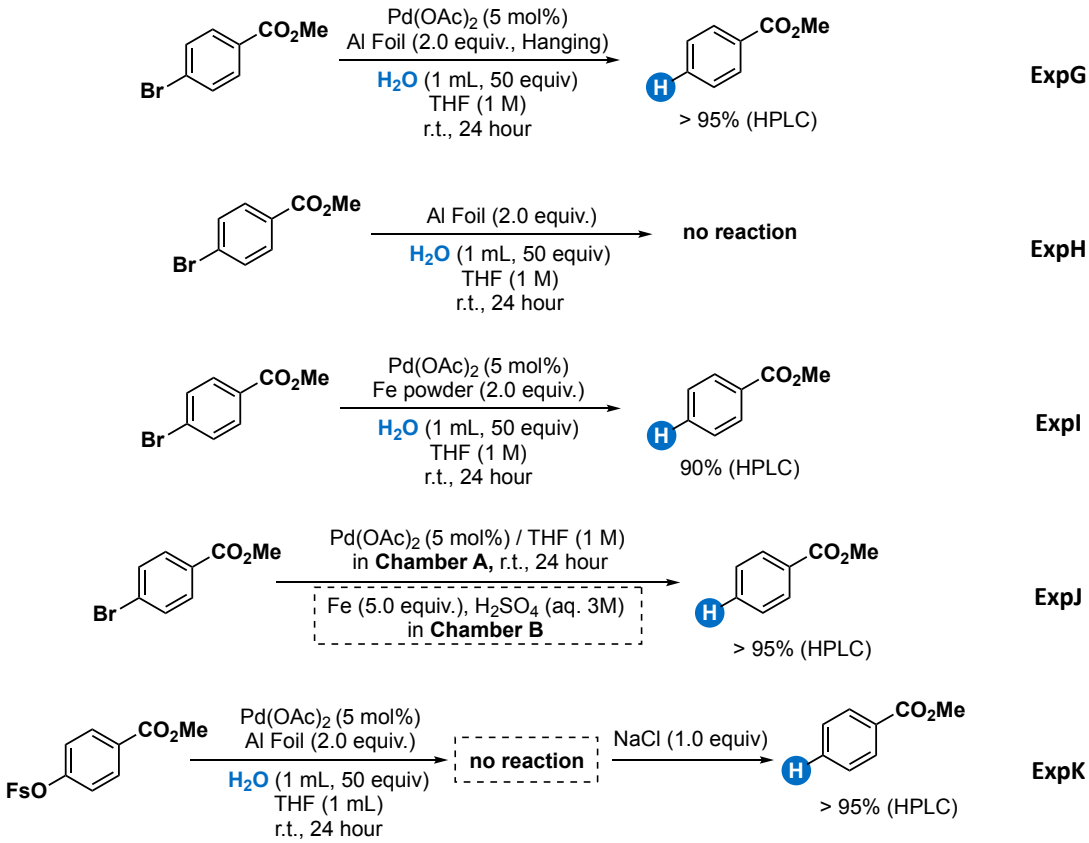
c) Mechanistic Investigation

Although the solution-based dehalogenation was firstly considered to undergo a similar mechanistic pathway as its mechanochemical counterpart. The kinetic difference as well as the distinguished substrate reactivity suggested the two transformations may occur in a different rhythm. Thus, experiments were designed to understand the reaction.

Firstly, aluminum foil was hanging in the mixture to avoid the potential mechanical abrasion (**ExpG**). The

reaction occurred smoothly, where the foil was corroded. We also confirmed the necessary of Pd-catalysis in the reaction (**ExpH**). Then, zero-valent iron were tested as reductant, which rendered a considerable yield of 90% this time (**ExpI**). With these results, we presumed the solution reaction was conducted via a hydrogen gas mediated dehalogenation. Thus, another two-chambers reaction was designed (**ExpJ**), where the H_2 generation and Pd-catalyzed dehalogenation were conducted in separated chamber. As expected, nearly stochiometric dehalogenation was observed. Thus, the reaction was conducted under H_2-medicated Pd-catalyzed dehalogenation, where the H_2 gas was generated by a bromide ion which mediated constant corrosion of aluminum oxide. With the curiosity of the performance of fluorosulfate ion in this metal oxide corrosion, aryl fluorosulfate was also tested under this solution condition (**ExpK**). However, the reaction failed to render any product after 24 hours stirring at room temperature. Further addition of NaCl leads to a complete transformation.

Therefore, based on the control experiments, a conventional Pd-catalyzed transfer deutero-dehalogenation mechanism was proposed (Figure S10), where D_2 gas was generated by *in-situ* aluminum reduction.



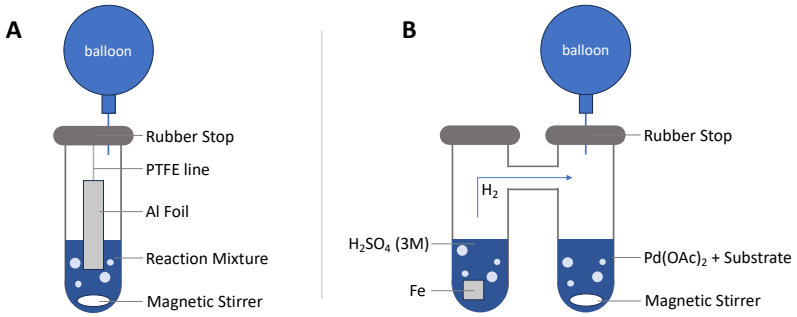


Figure S9 Reaction setup for experiment G (**A**) and experiment J (**B**).

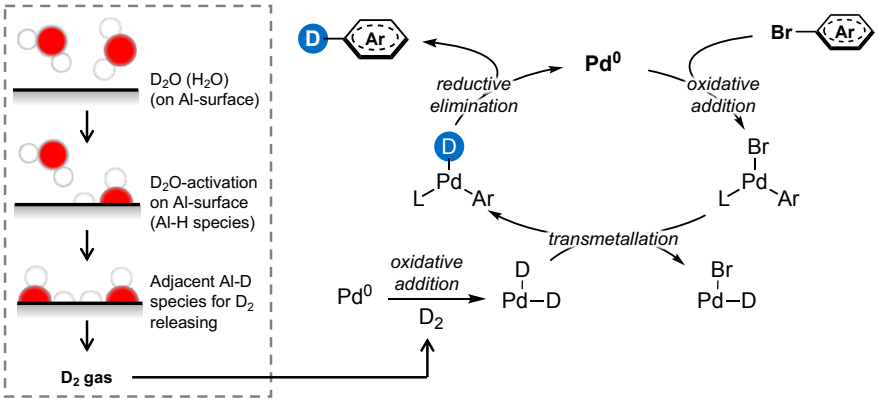


Figure S10 Mechanism proposed for solution condition.

Experimental procedure of ExpG: A mixture of methyl 4-bromobenzoate (215 mg, 1.0 mmol), $Pd(OAc)_2$ (9.7 mg, 5 mol %), THF (1.0 mL), and H_2O (1.0 mL) were added to a 5 mL round bottom flask. Aluminum foil (54 mg, 2.0 mmol) was hung above the magneton by Teflon rope, the bottom was sealed with balloon, and stirred at room temperature for 24 h. At the end of the reaction, H_2O (10 mL) was added and extracted by DCM (10 mL × 3). The organic layer was dried over sodium sulfate and the yield was >95% which was determined by HPLC.

Experimental procedure of ExpH: A mixture of methyl 4-bromobenzoate (215 mg, 1.0 mmol), aluminum foil (54 mg, 2.0 mmol), THF (1.0 mL), and H_2O (1.0 mL) were added to a 5 mL round bottom flask sealed with balloon, and stir at room temperature for 24 h. At the end of the reaction, H_2O (10 mL) was added and extracted by DCM (10 mL × 3). The organic layer was dried over sodium sulfate and no product was detected by HPLC.

Experimental procedure of ExpI: A mixture of methyl 4-bromobenzoate (215 mg, 1.0 mmol), iron powder (118 mg, 2.0 mmol), $Pd(OAc)_2$ (11.2 mg, 5 mol %), THF (1.0 mL), and H_2O (1.0 mL) were added to a 5 mL round bottom flask sealed with balloon, and stir at room temperature for 24 h. At the end of the reaction, H_2O (10 mL) was added and extracted by DCM (10 mL × 3). The organic layer was dried over sodium sulfate and the yield was 90% which was determined by HPLC.

Experimental procedure of ExpJ: A mixture of methyl 4-bromobenzoate (108mg, 0.5 mmol), $Pd(OAc)_2$ (5.6mg, 5 mol %) and THF (0.5 mL) were added to chamber **A**. Fe powder (280 mg, 5.0 mmol) was added to chamber **B**, subsequently, 3 M H_2SO_4 (2.0 mL) add to chamber **B** to generate H_2 and stir at room temperature for 24 h. At the end of the reaction, H_2O (10 mL) was added to chamber **A** and extracted by DCM (10 mL × 3). The organic layer was dried over sodium sulfate and the yield was > 95% which was determined by HPLC.

Experimental procedure of ExpK: A mixture of 4-fluorosulfate-ethyl-benzoate (245mg, 1.0 mmol), aluminum foil (54 mg, 2.0 mmol), $Pd(OAc)_2$ (11.2 mg, 5 mol %), THF (1.0 mL), and H_2O (1.0 mL) were added to a 5 mL round bottom flask sealed with balloon, and stir at room temperature for 24 h. Subsequently, take a small amount of samples use HPLC

to analyze and no product was detected. After that, add NaCl (58 mg, 1.0 mmol) and stir for 24 h again. At the end of reaction, H_2O (10 mL) was added and extracted by DCM (10 mL × 3). The organic layer was dried over sodium sulfate and the yield was >95% which was determined by HPLC.

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8. Copies of ^{1}H NMR and ^{13}C NMR spectrum

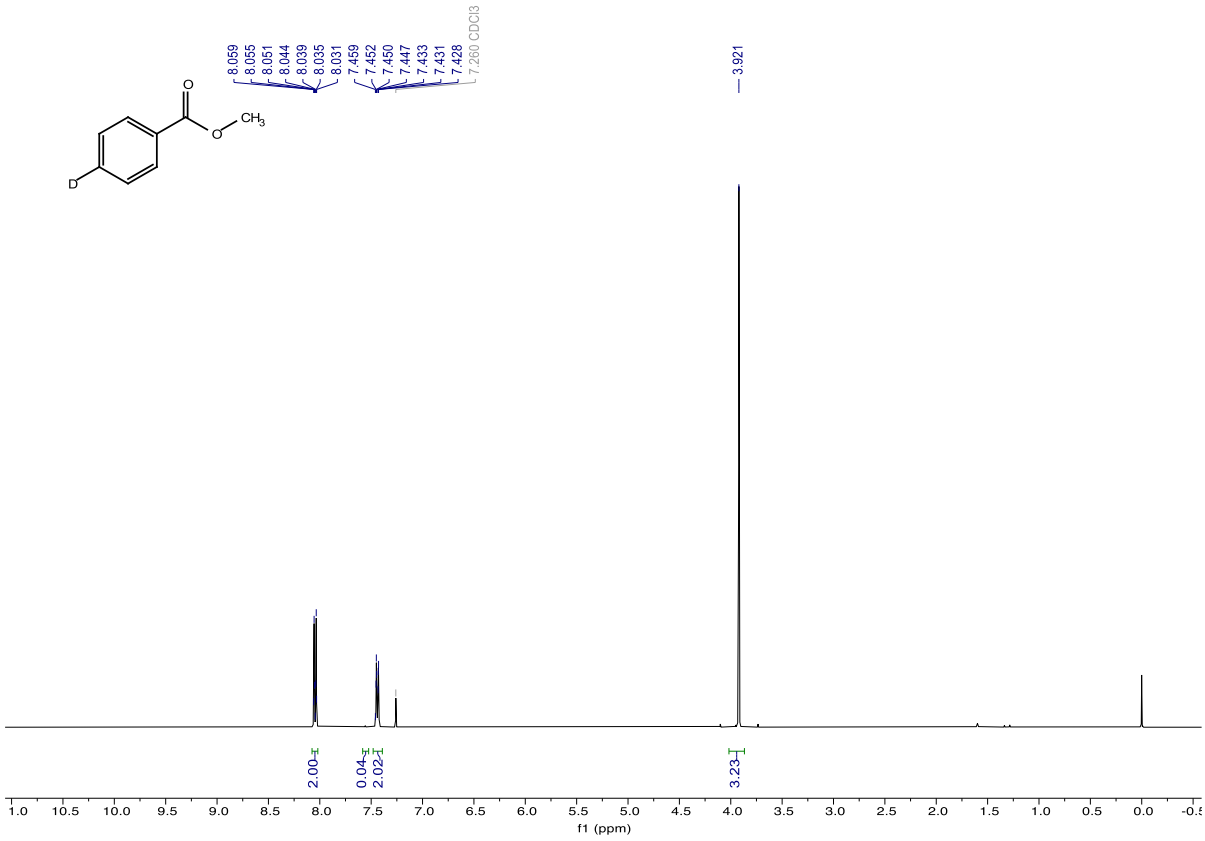

Figure S11 ^{1}H NMR of **1-[d]** in Chloroform-*d*

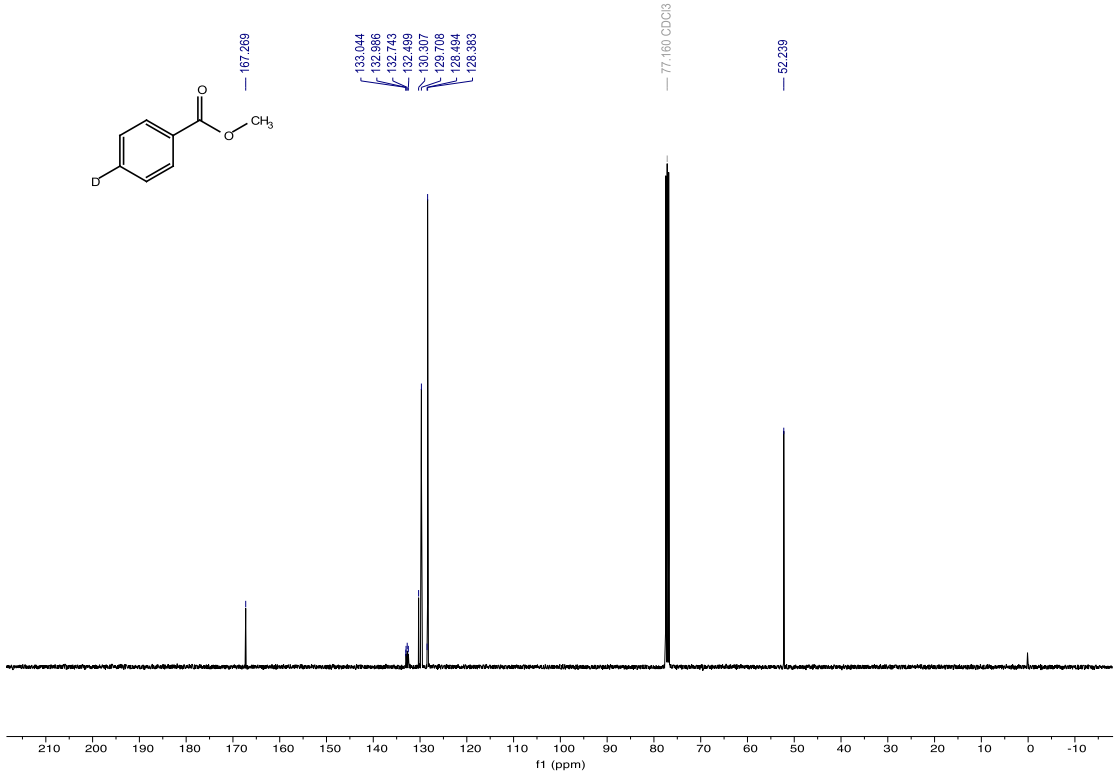

Figure S12 ^{13}C NMR of **1-[d]** in Chloroform-*d*

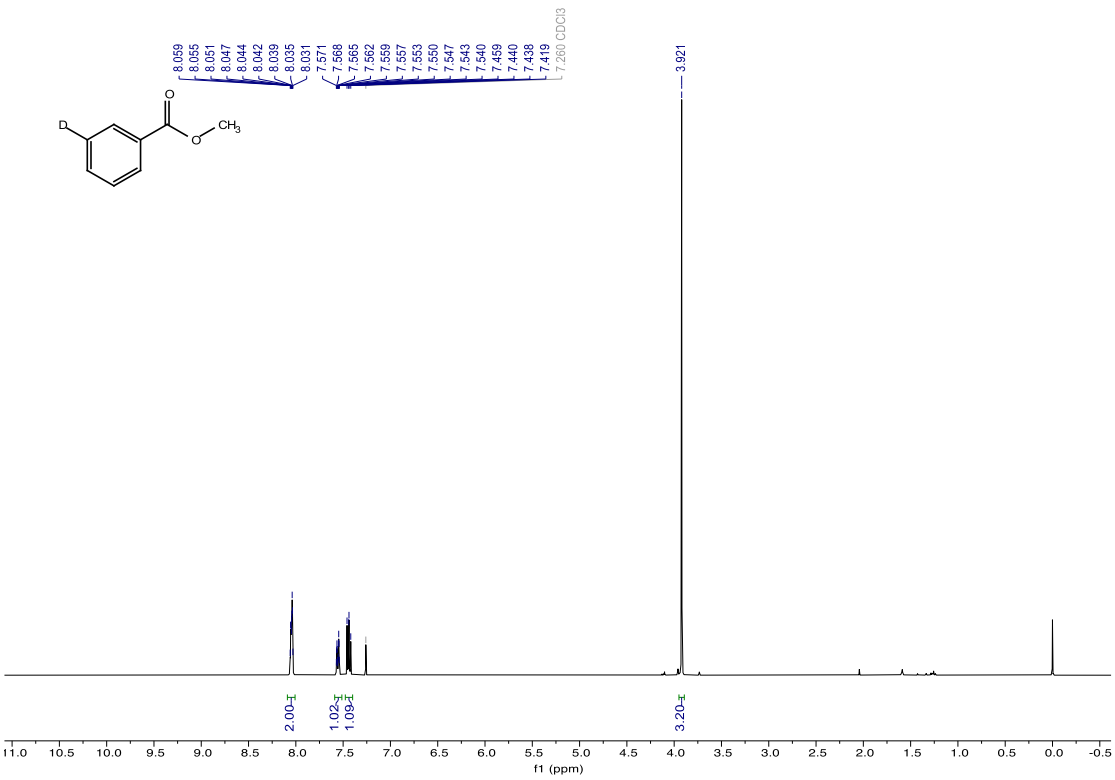

Figure S13 ^{1}H NMR of **2-[d]** in Chloroform-*d*

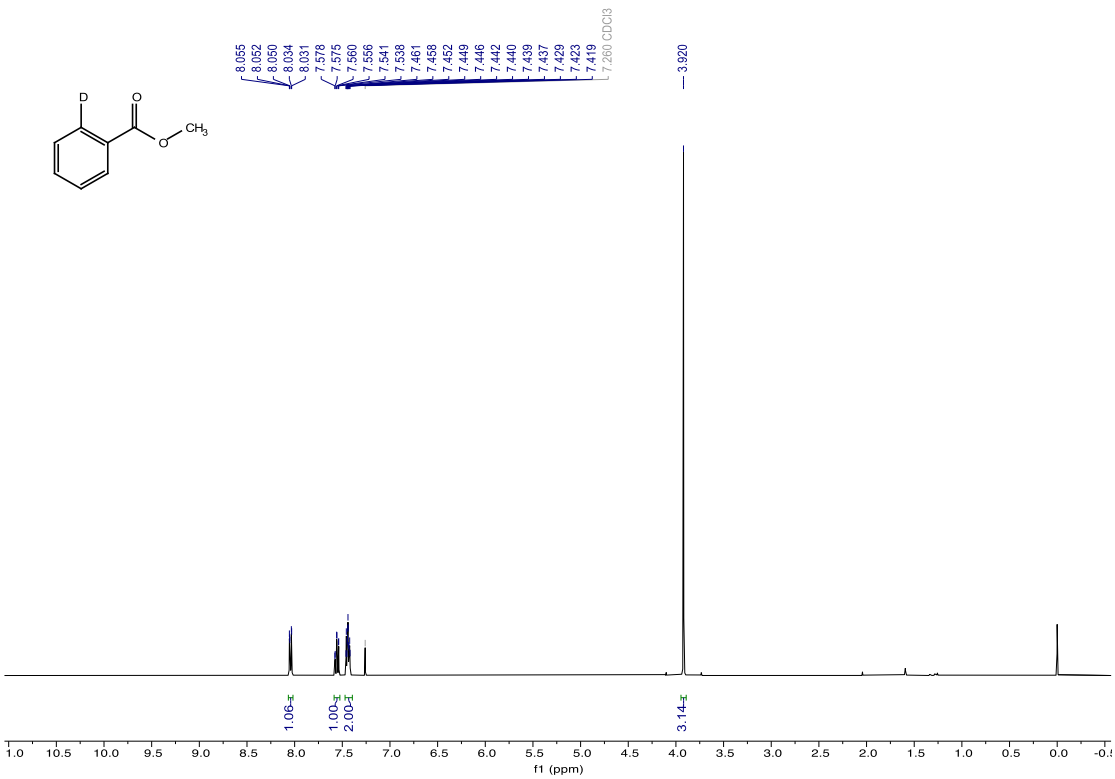

Figure S14 ^{1}H NMR of **3-[d]** in Chloroform-*d*

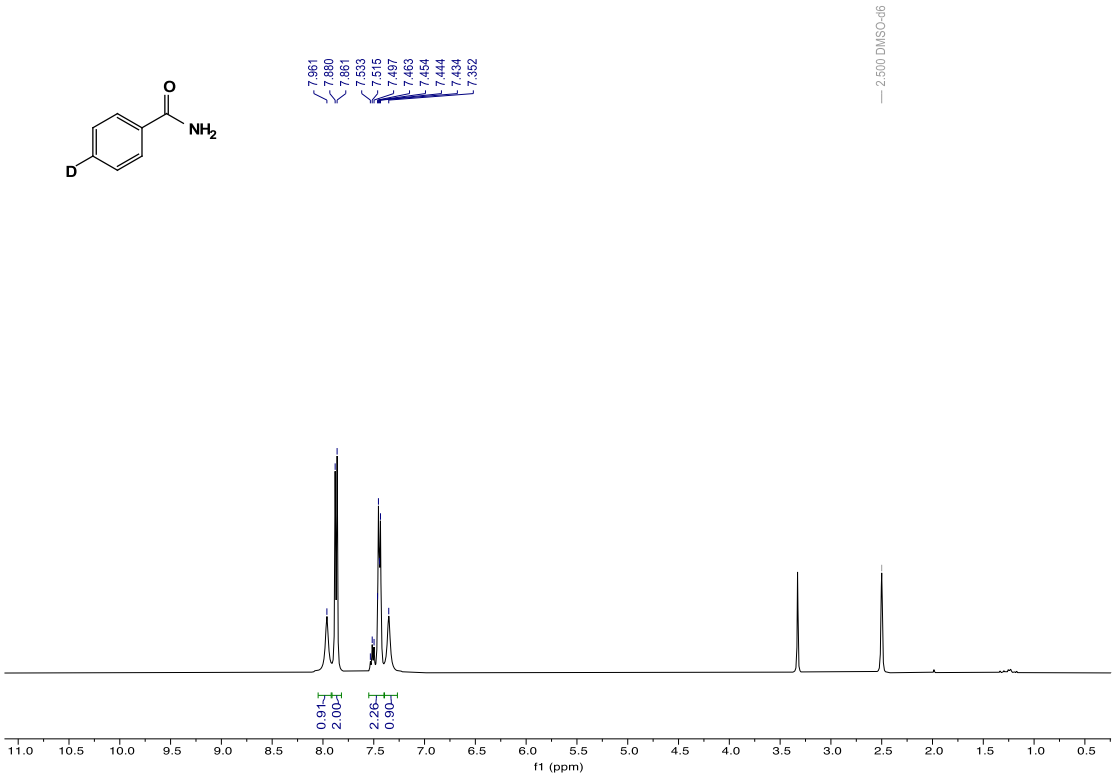

Figure S15 ^{1}H NMR of **4-[d]** in Chloroform-*d*

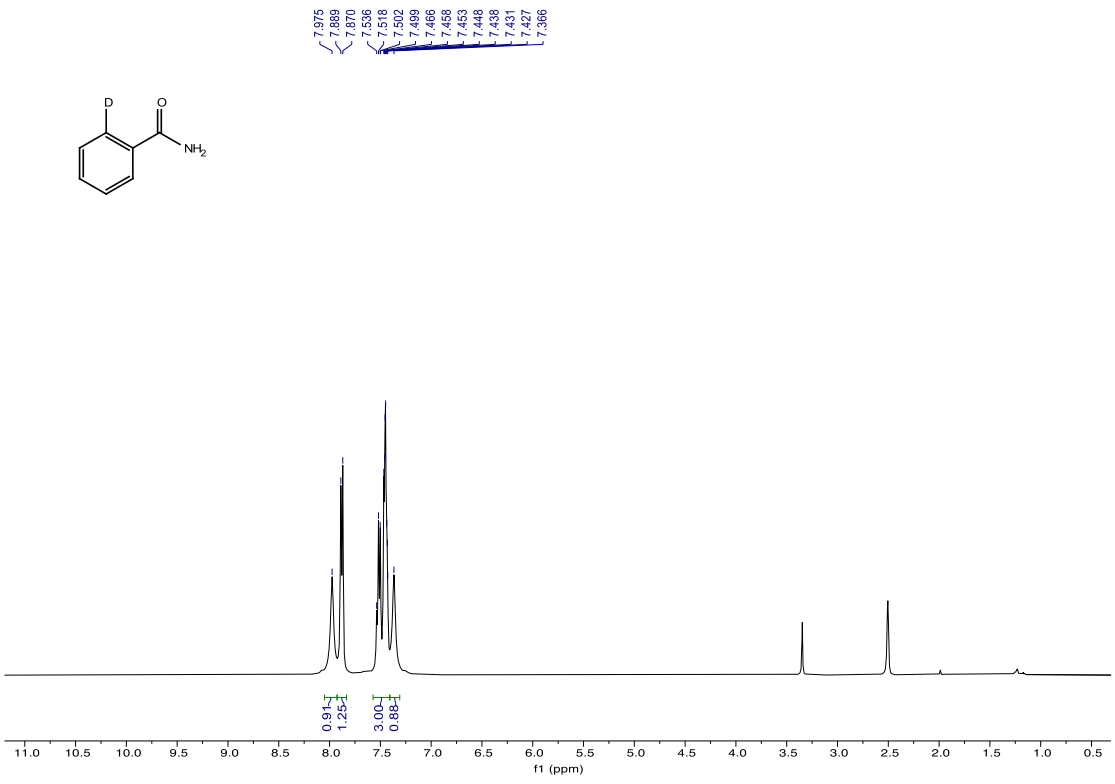

Figure S16 ^{1}H NMR of **5-[d]** in Chloroform-*d*

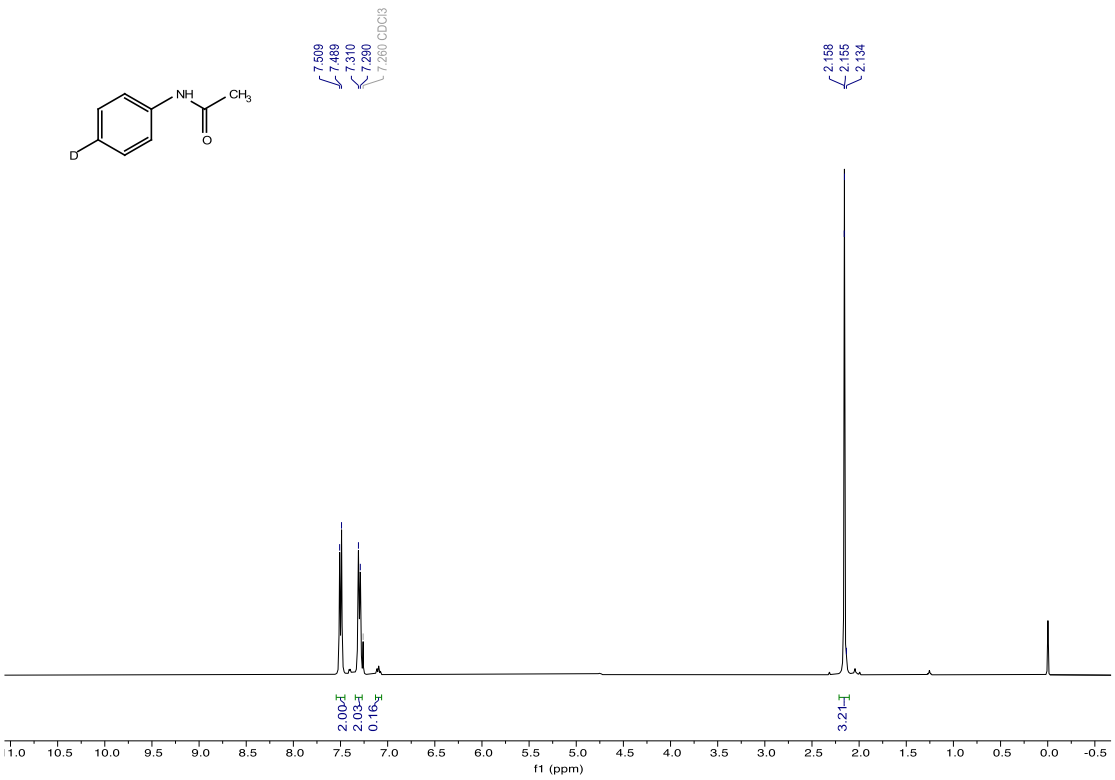

Figure S17 ^{1}H NMR of **9-[d]** in Chloroform-*d*

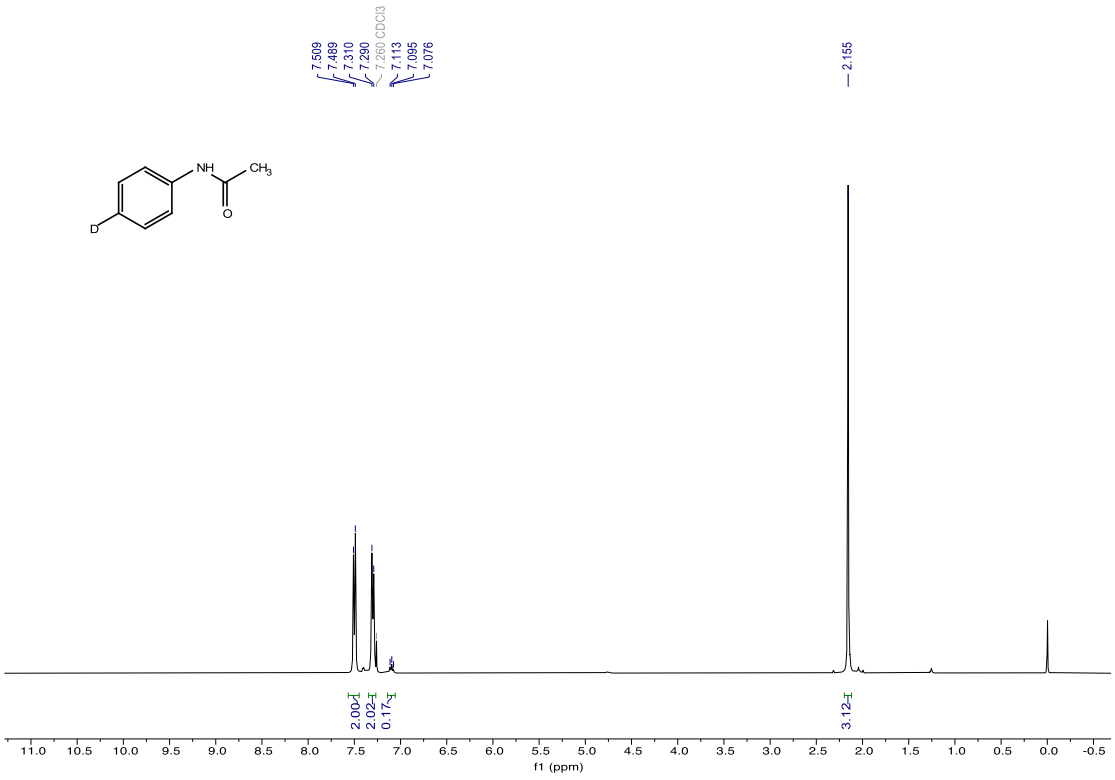

Figure S18 ^{1}H NMR of **9-[d]-scaling** in Chloroform-*d*

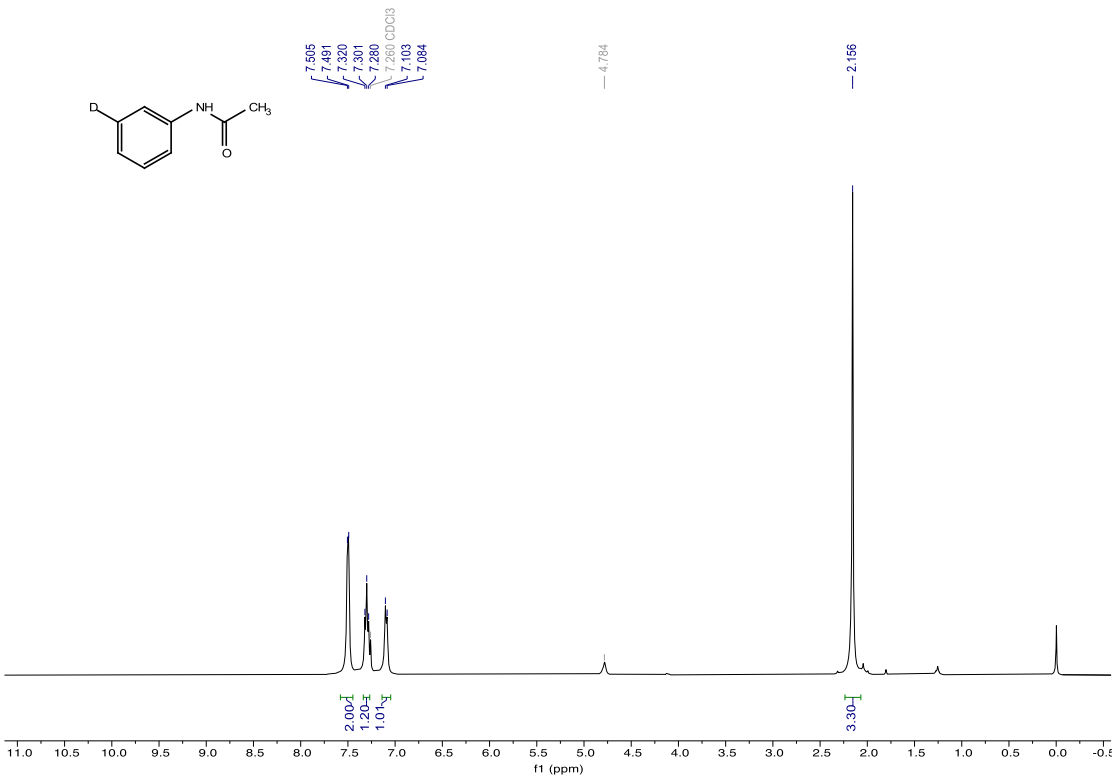

Figure S19 ^{1}H NMR of **10-[d]** in Chloroform-*d*

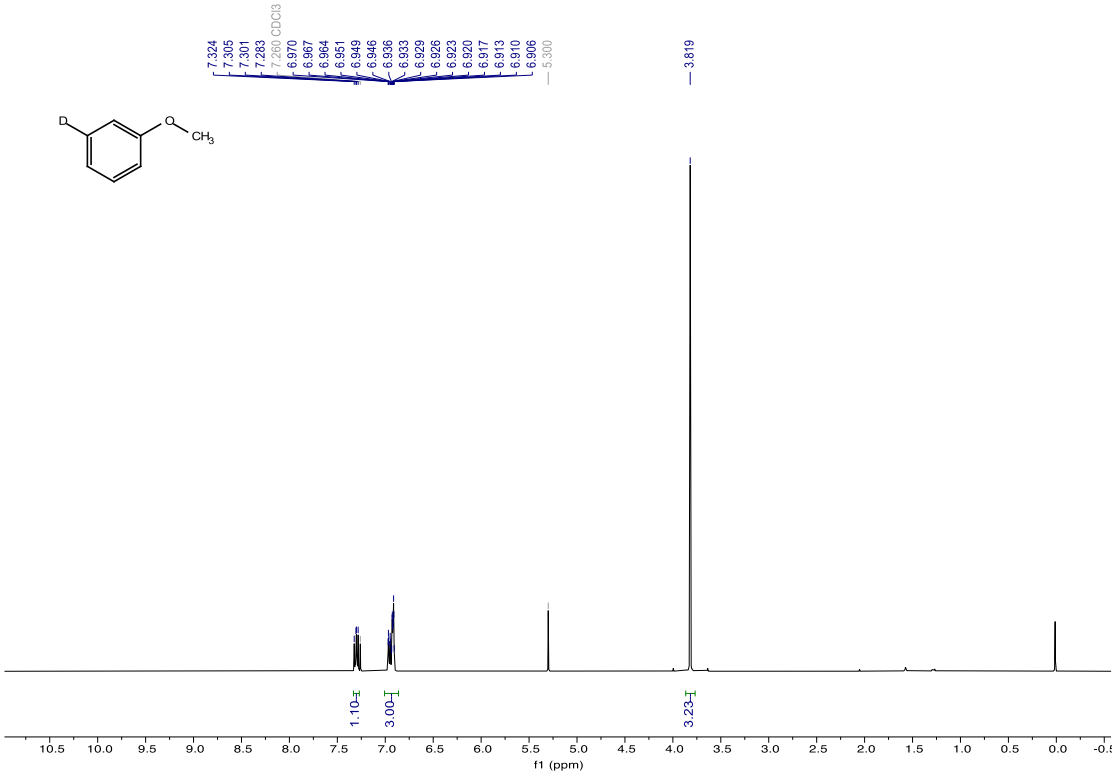

Figure S20 ^{1}H NMR of **11-[d]** in Chloroform-*d*

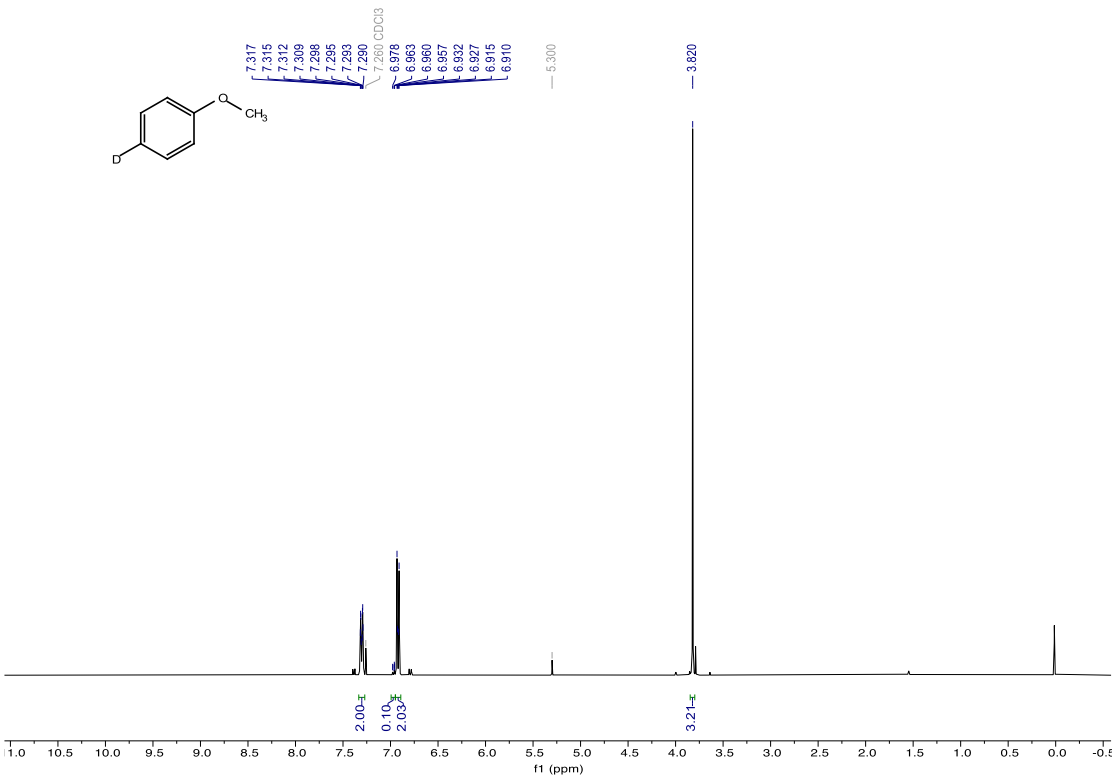

Figure S21 ^{1}H NMR of **12-[d]** in Chloroform-*d*

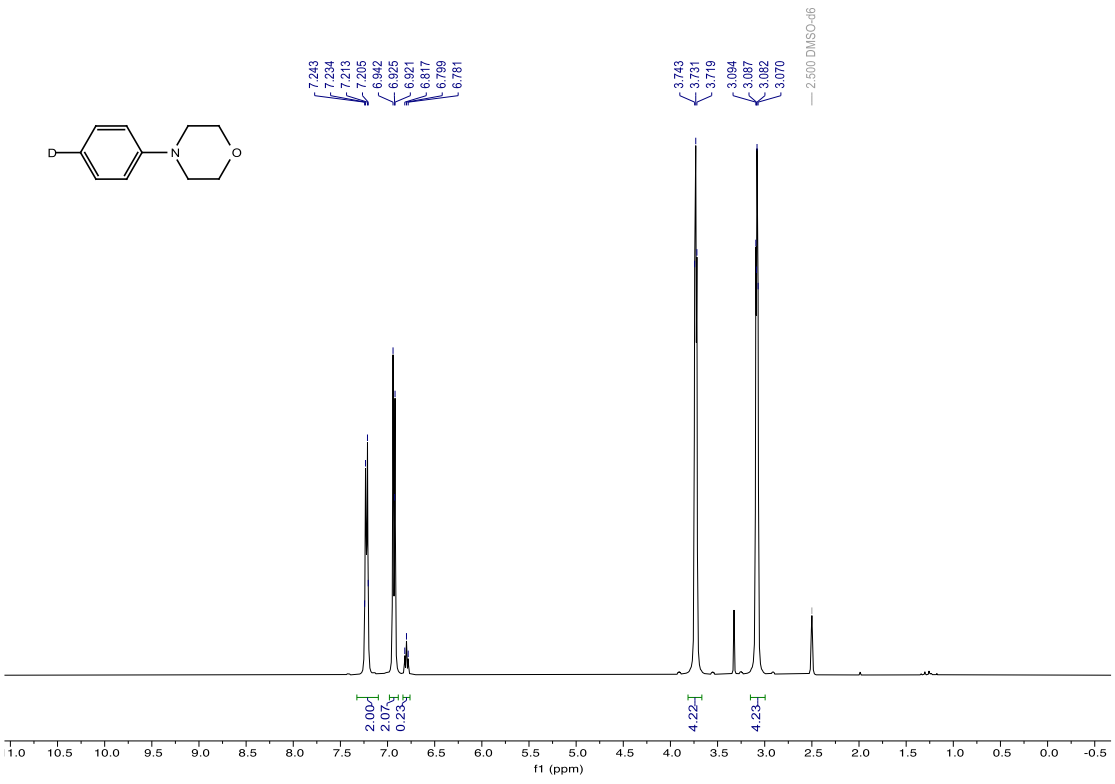

Figure S22 ^{1}H NMR of **13-[d]** in DMSO-d_6

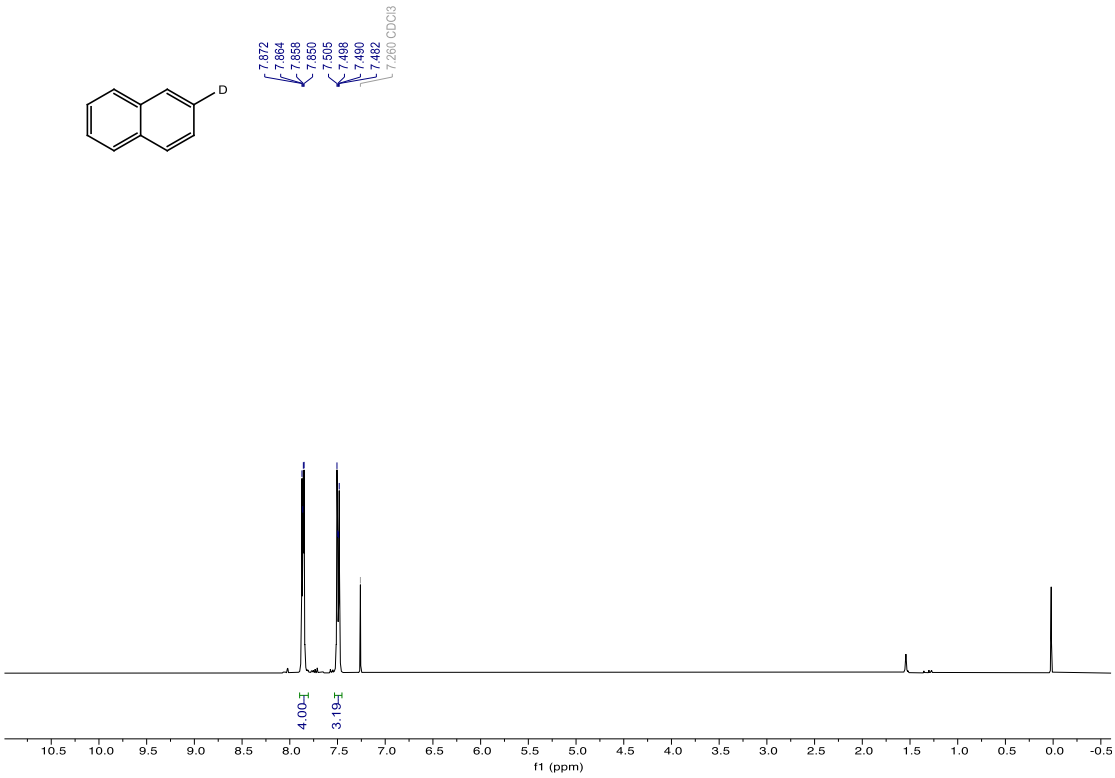

Figure S23 ^{1}H NMR of **14-[d]** in Chloroform-*d*

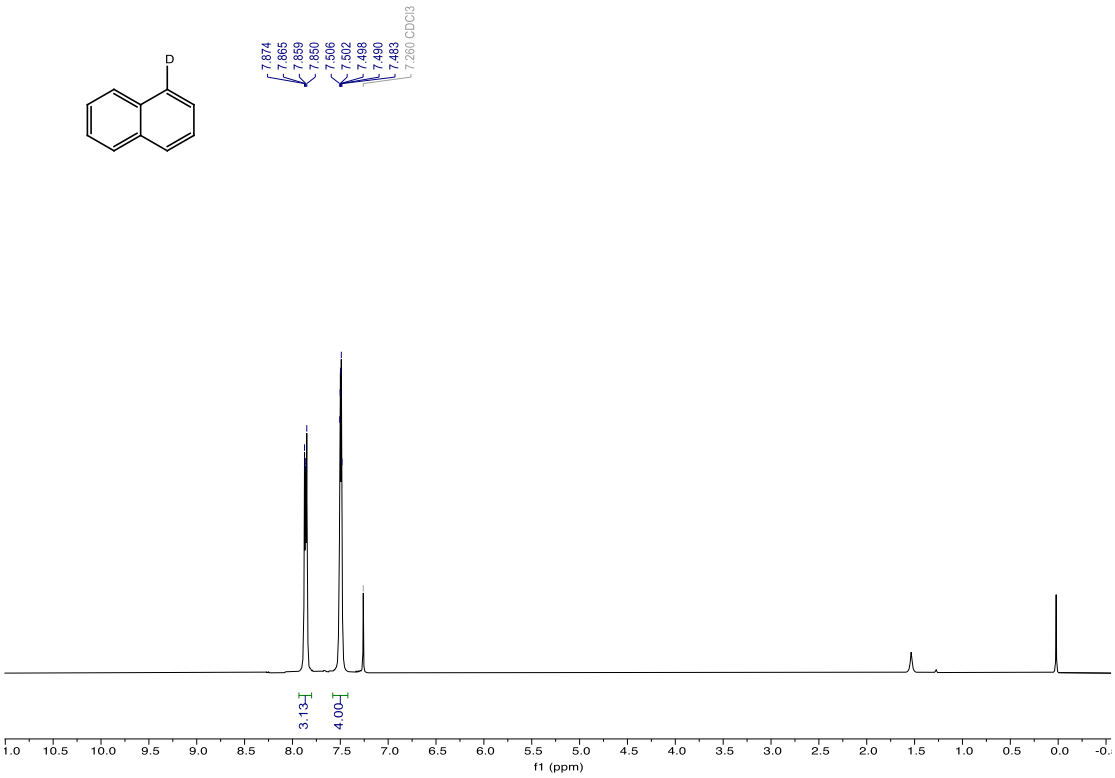

Figure S24 ^{1}H NMR of **15-[d]** in Chloroform-*d*

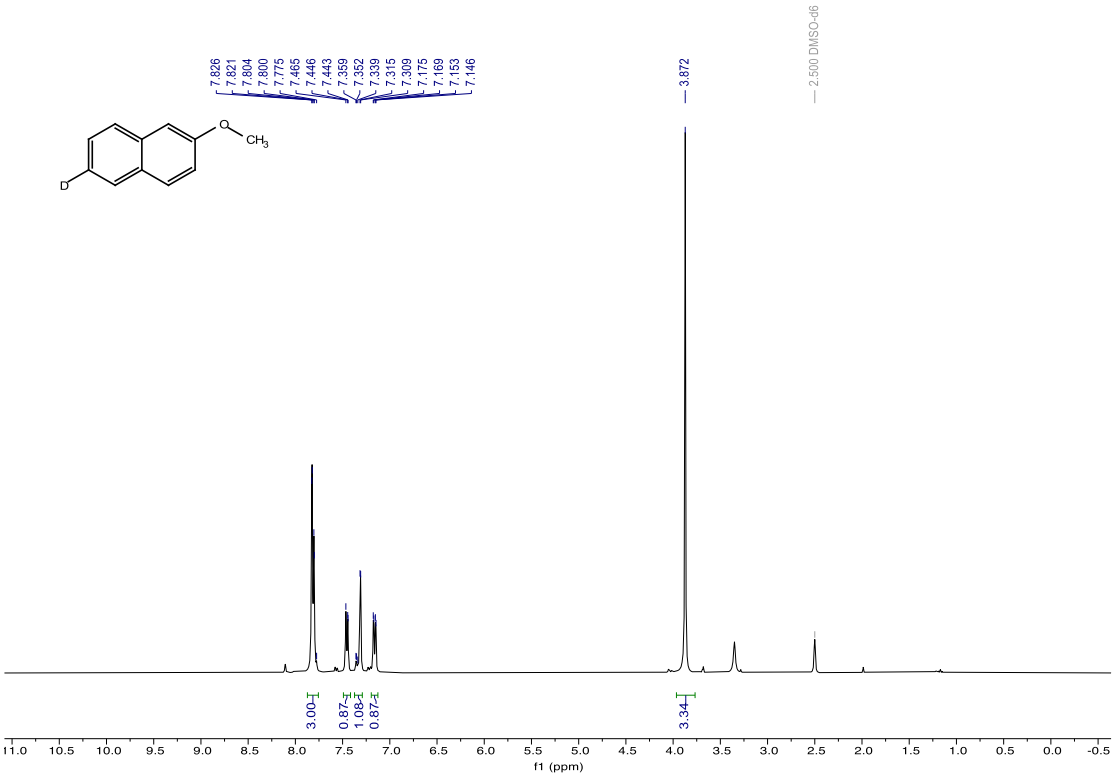

Figure S25 ^{1}H NMR of **16-[d]** in Chloroform-*d*

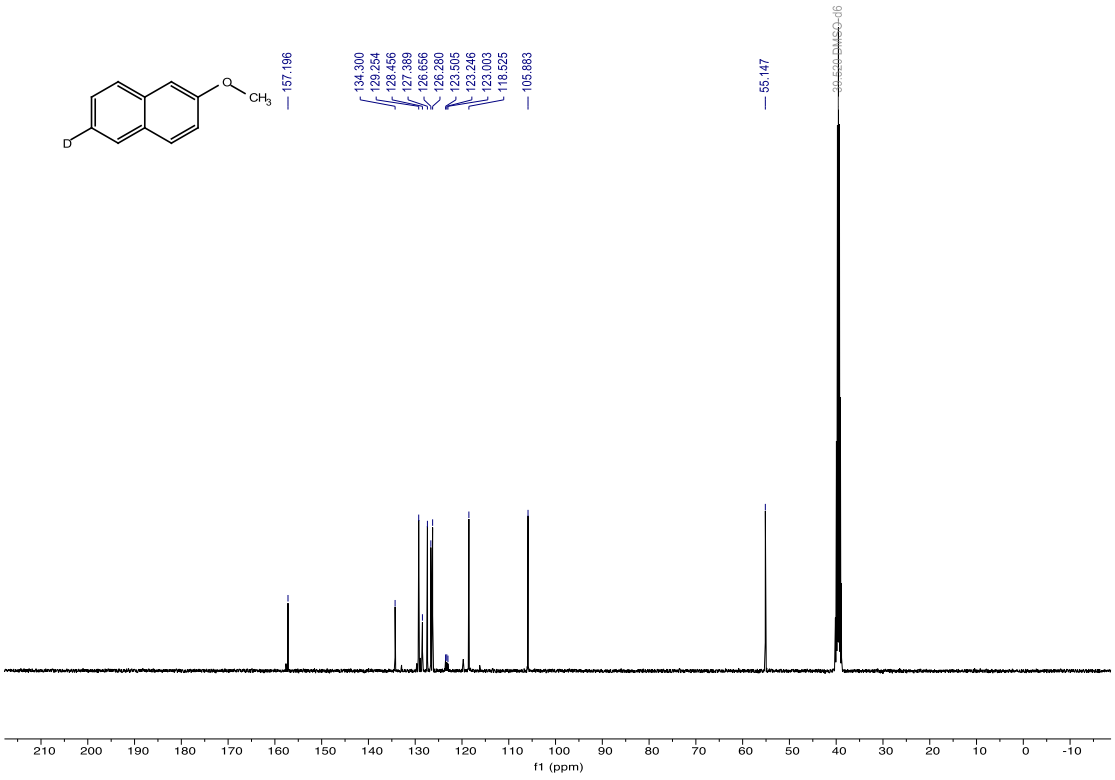

Figure S26 ^{13}C NMR of **16-[d]** in Chloroform-*d*

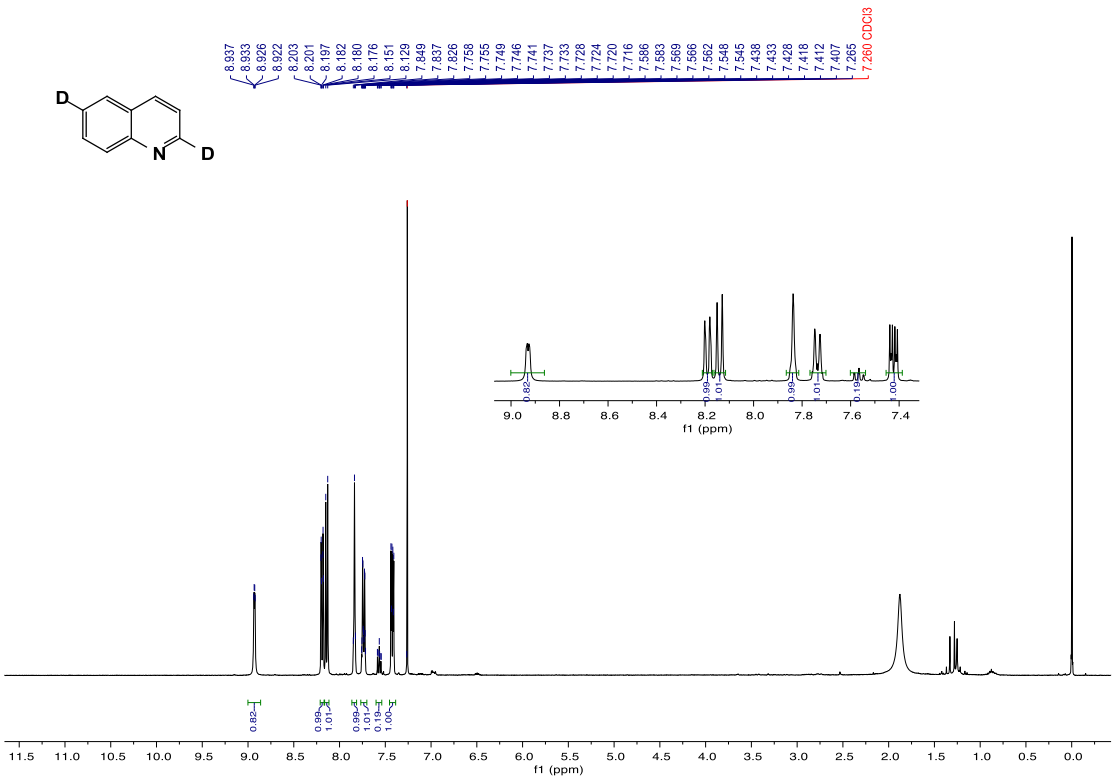

Figure S27 ^{1}H NMR of **17-[d]** in Chloroform-*d*

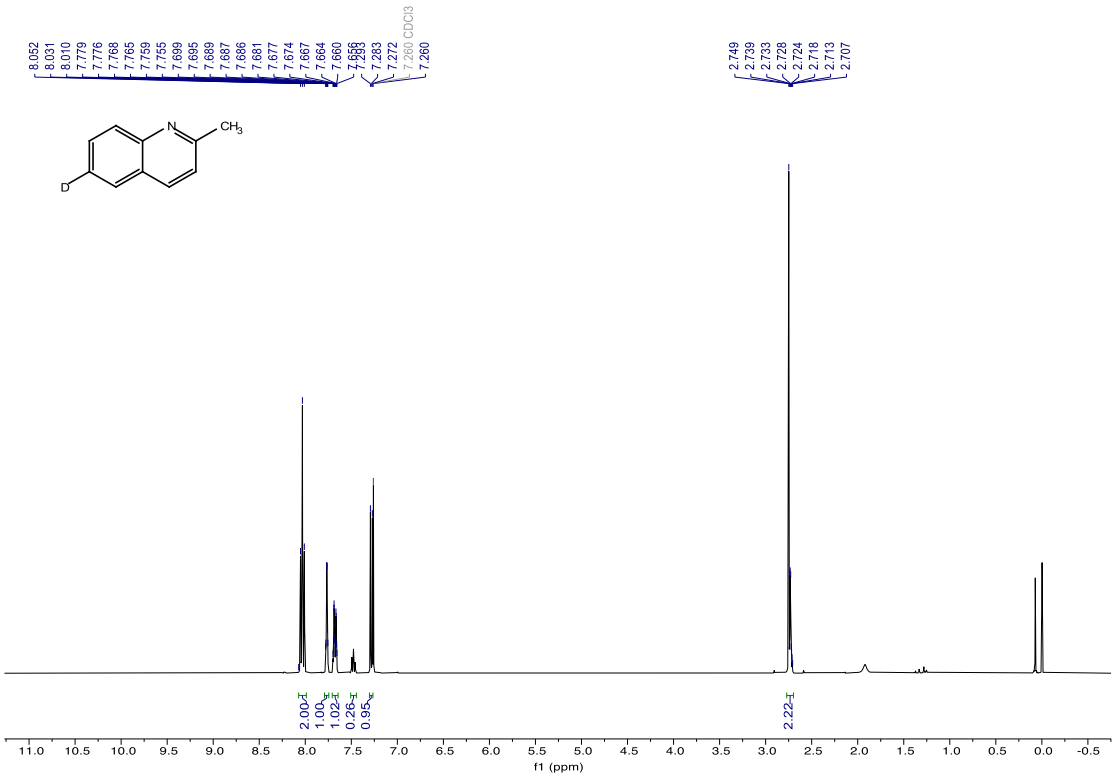

Figure S28 ^{1}H NMR of **18-[d]** in Chloroform-*d*

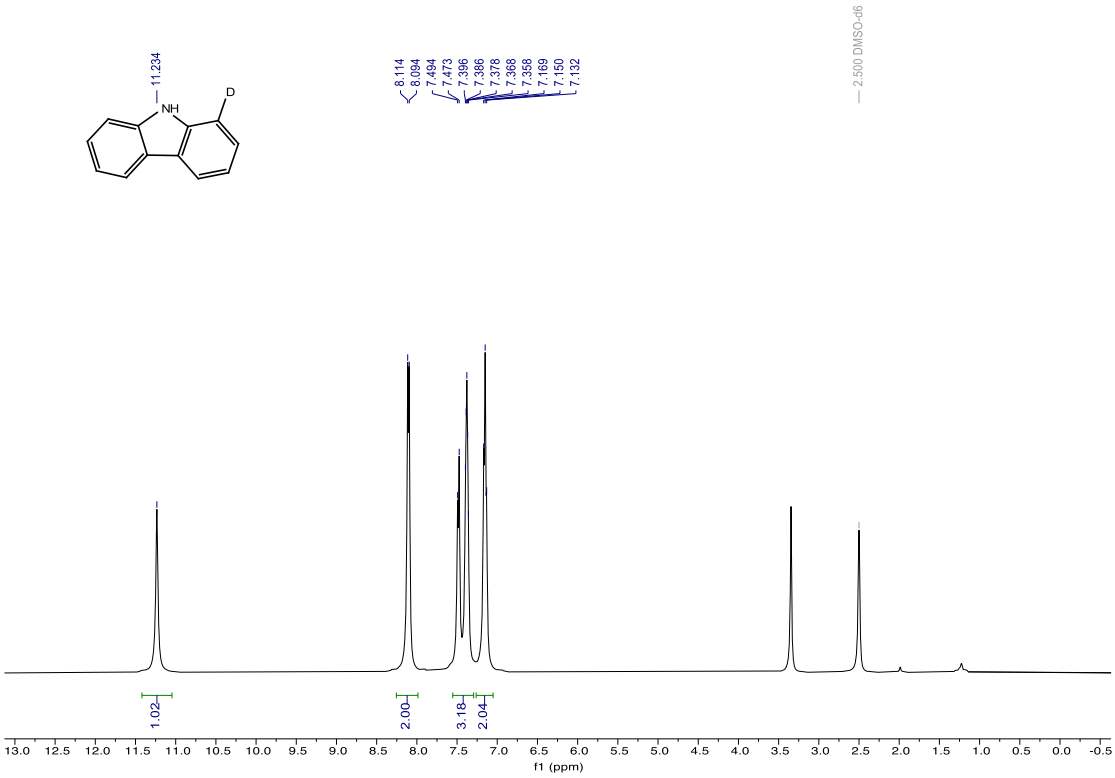

Figure S29 ^{1}H NMR of **19-[d]** in DMSO-d_6

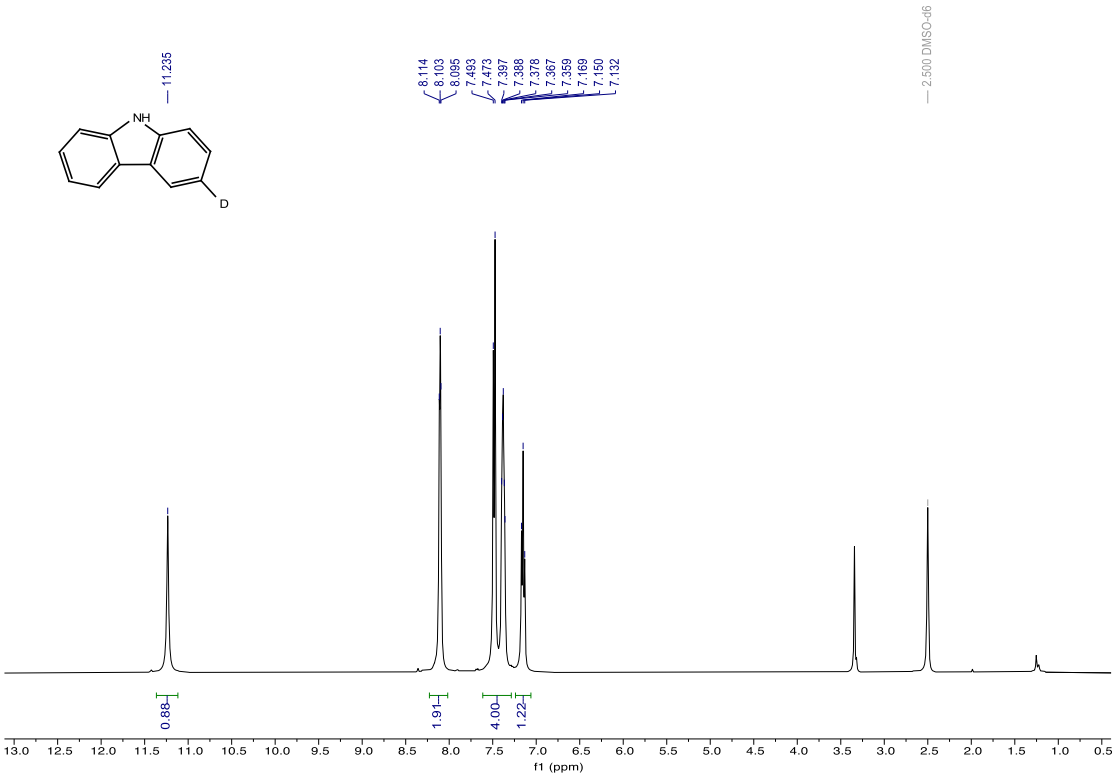

Figure S30 ^{1}H NMR of **20-[d]** in DMSO-d_6

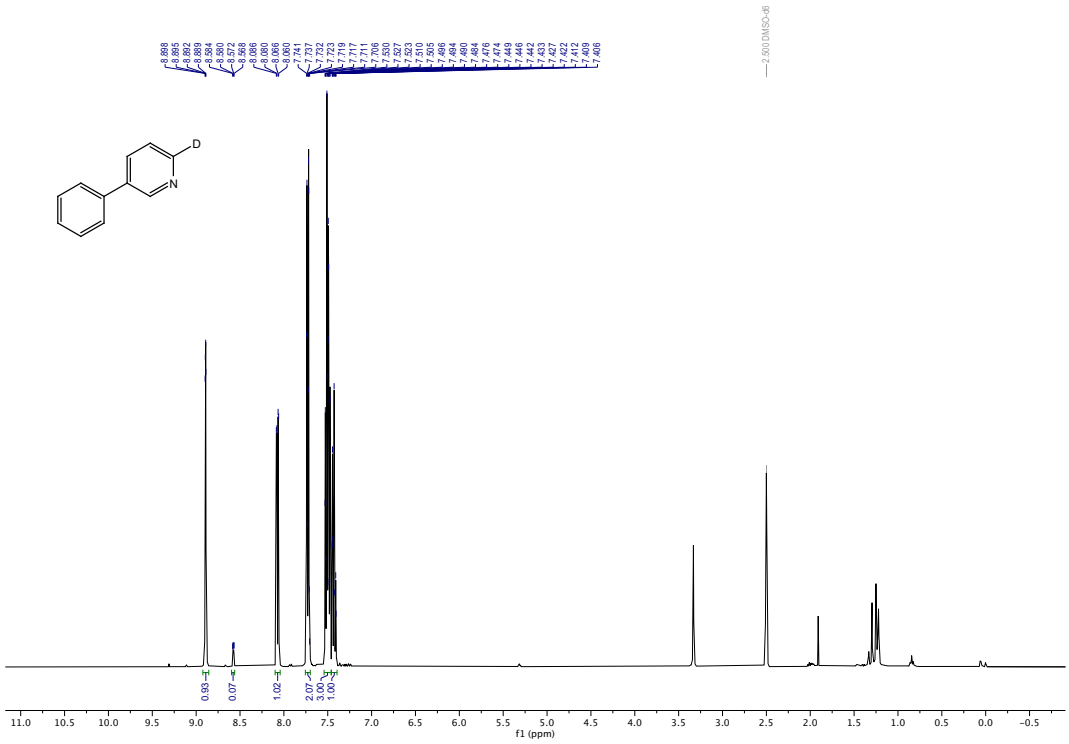

Figure S31 ^{1}H NMR of **21-[d]** in DMSO-d_6

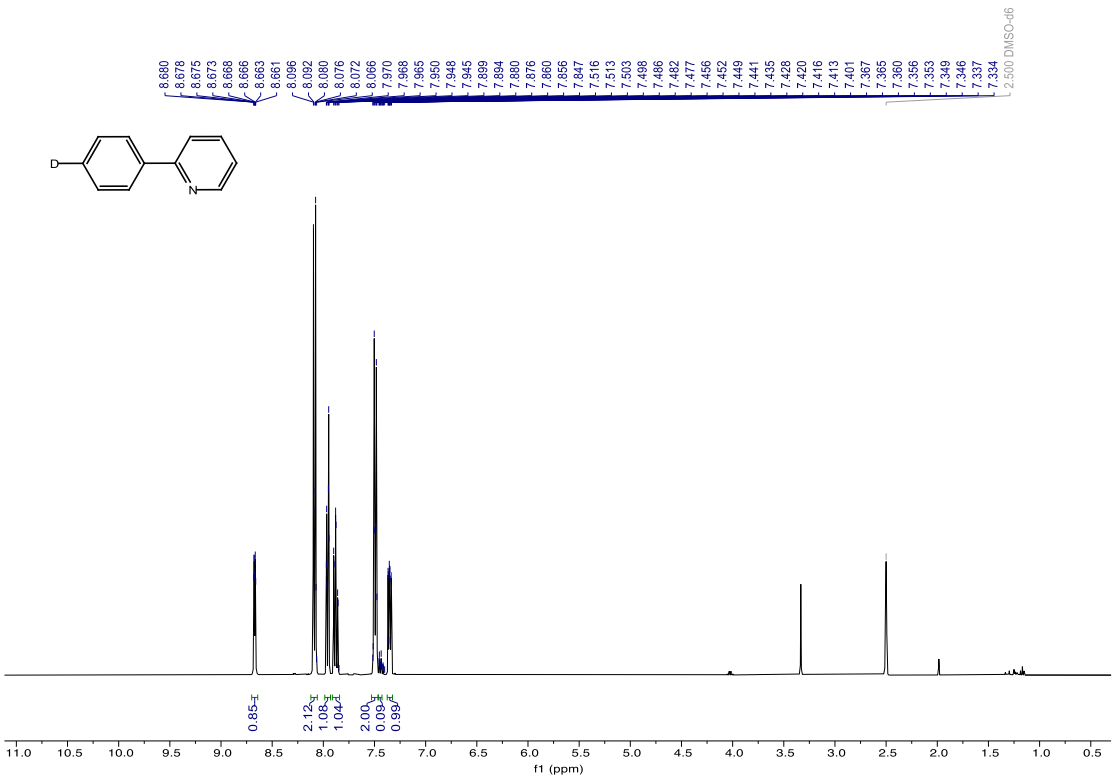

Figure S32 ^{1}H NMR of **22-[d]** in Chloroform-*d*

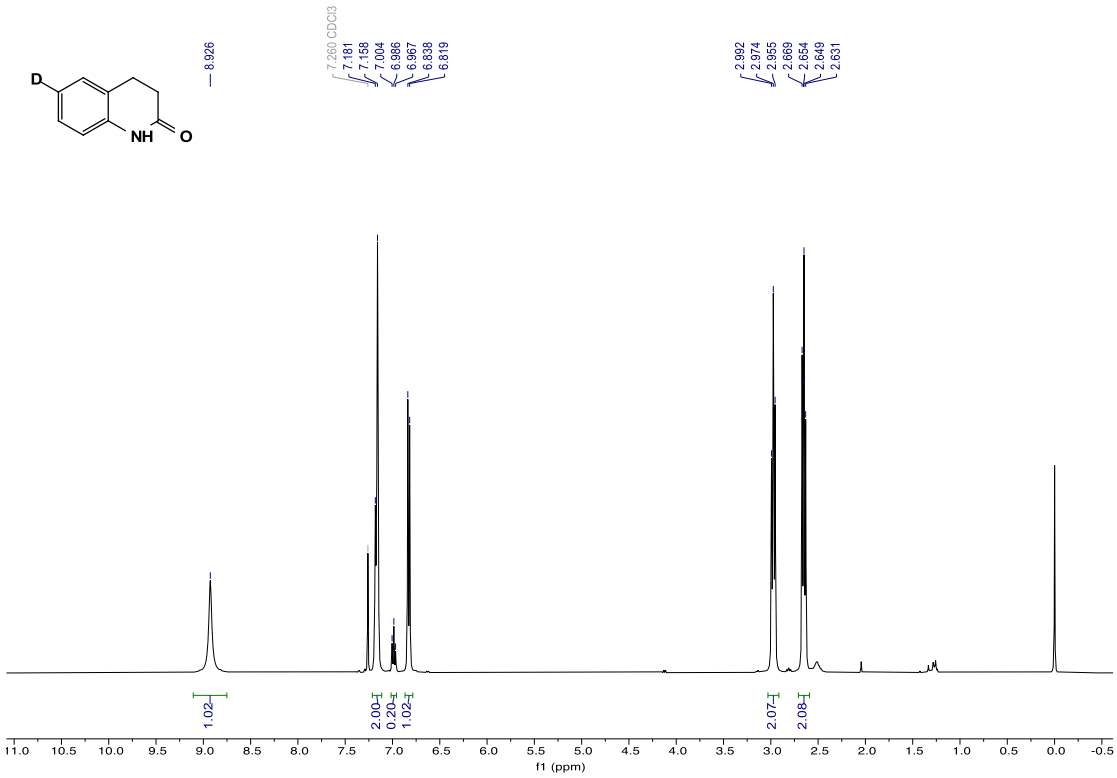

Figure S33 ^{1}H NMR of **23-[d]** in Chloroform-*d*

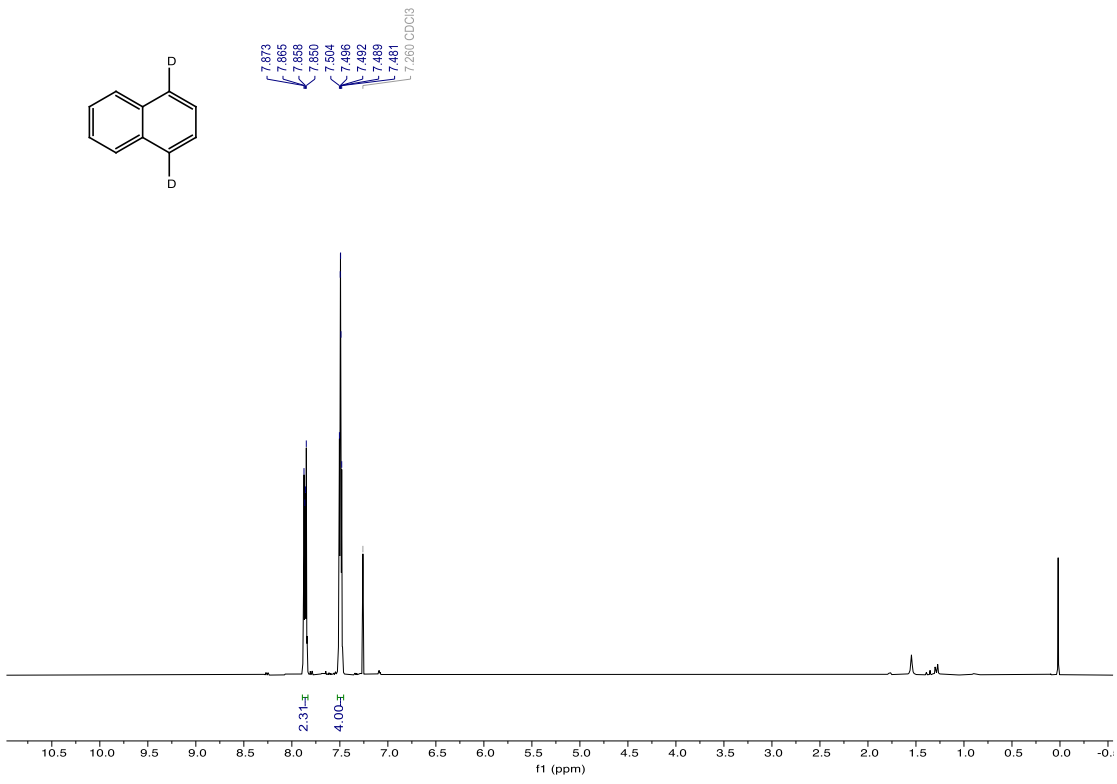

Figure S34 ^{1}H NMR of **24-[d]-2Br** in Chloroform-*d*

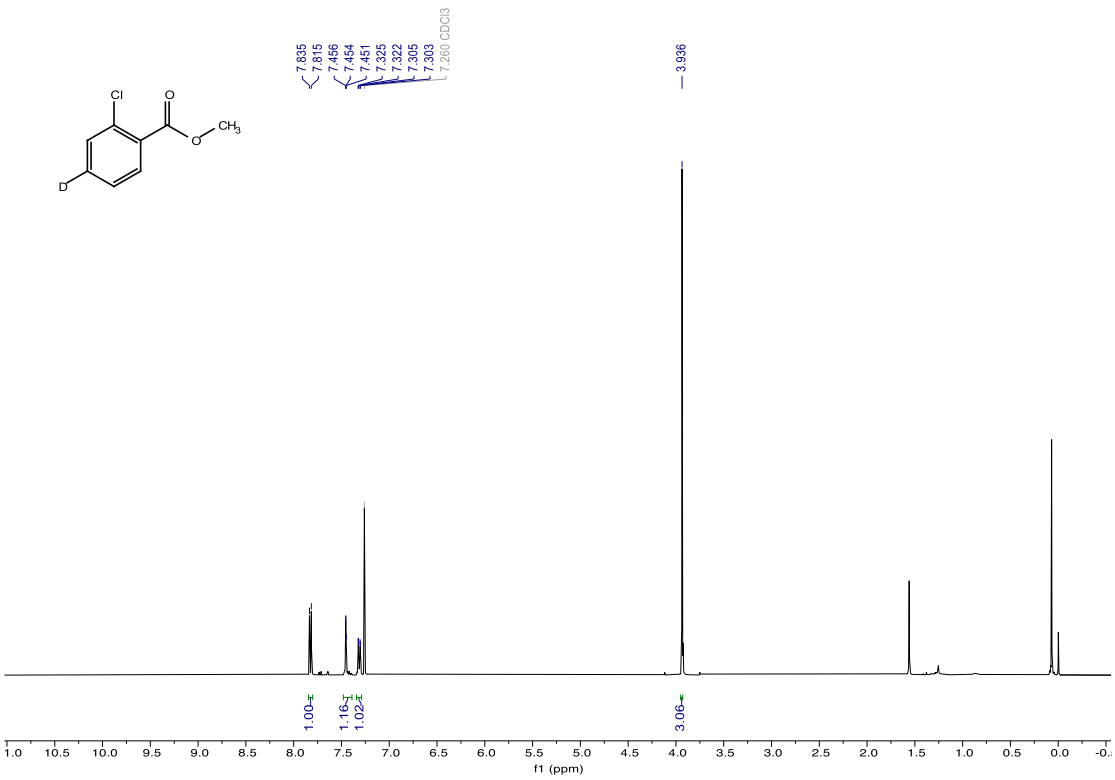

Figure S35 ^{1}H NMR of **25-[d]** in Chloroform-*d*

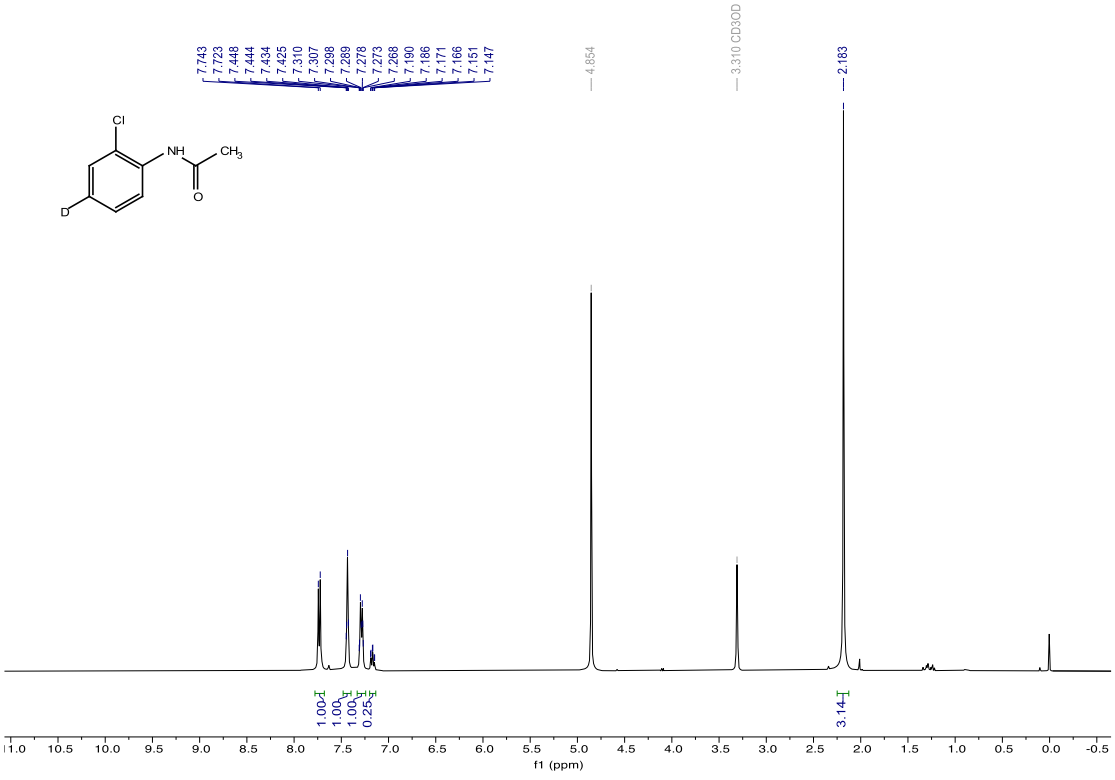

Figure S36 ^{1}H NMR of **26-[d]** in CD_3OD-d_4

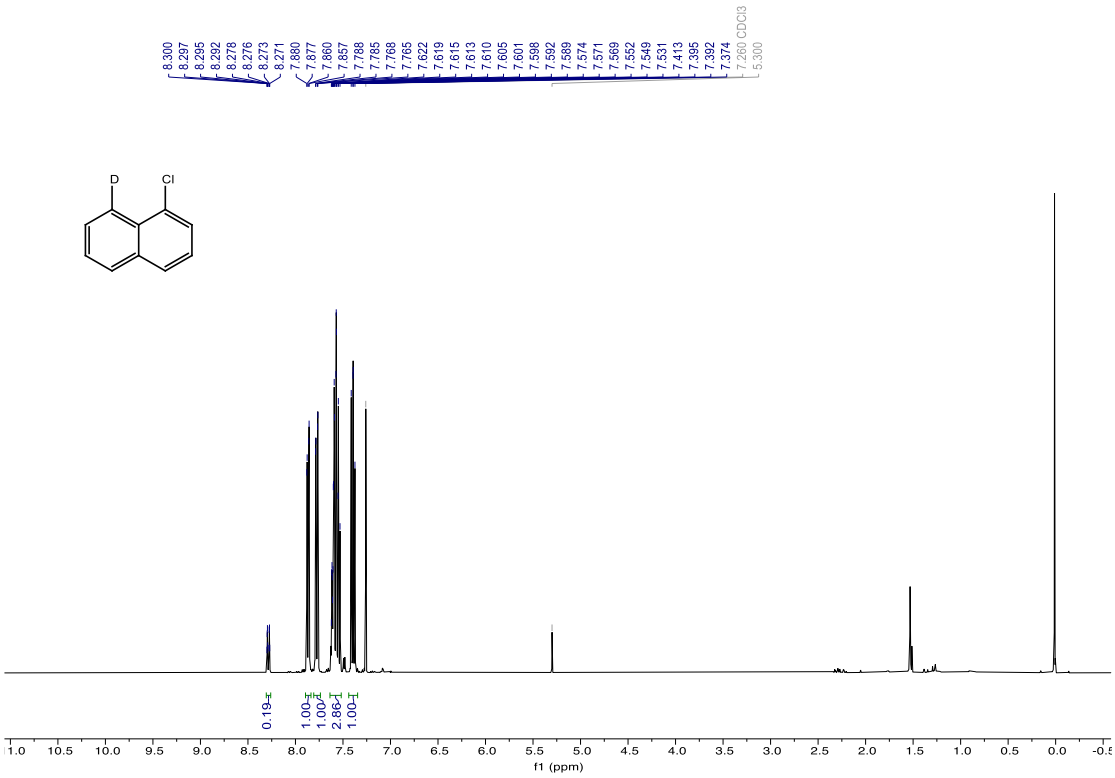

Figure S37 ^{1}H NMR of **27-[d]** in Chloroform-*d*

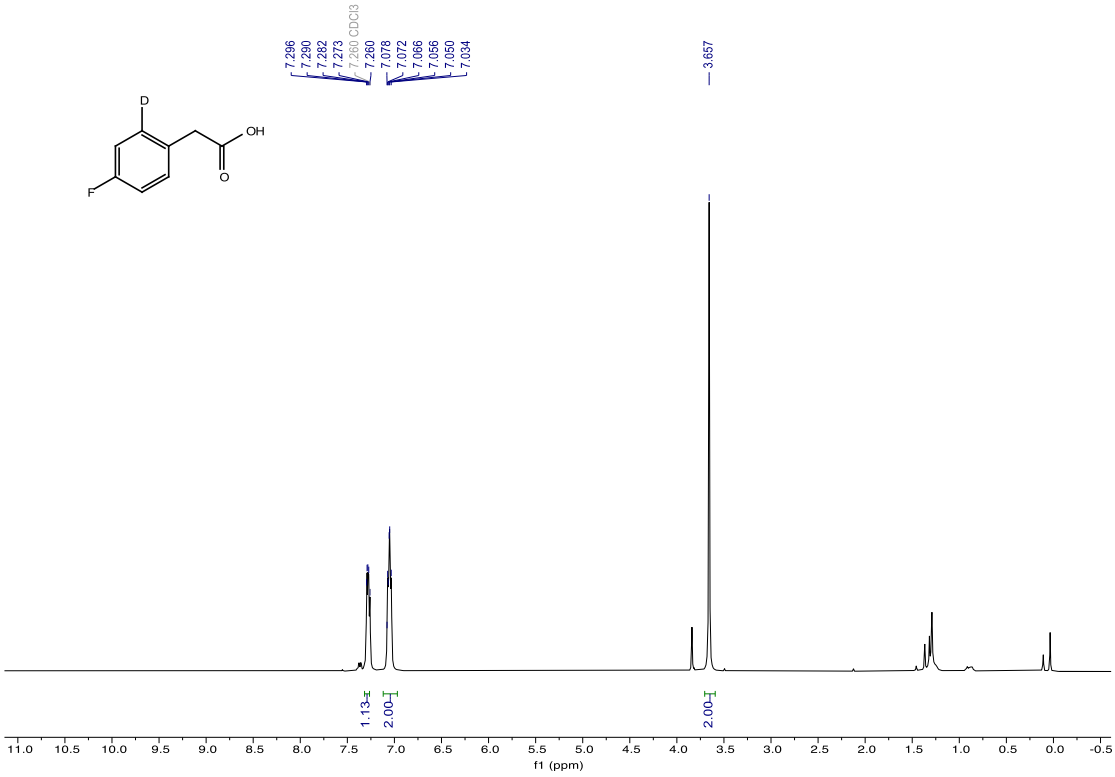

Figure S38 ^{1}H NMR of **28-[d]** in Chloroform-*d*

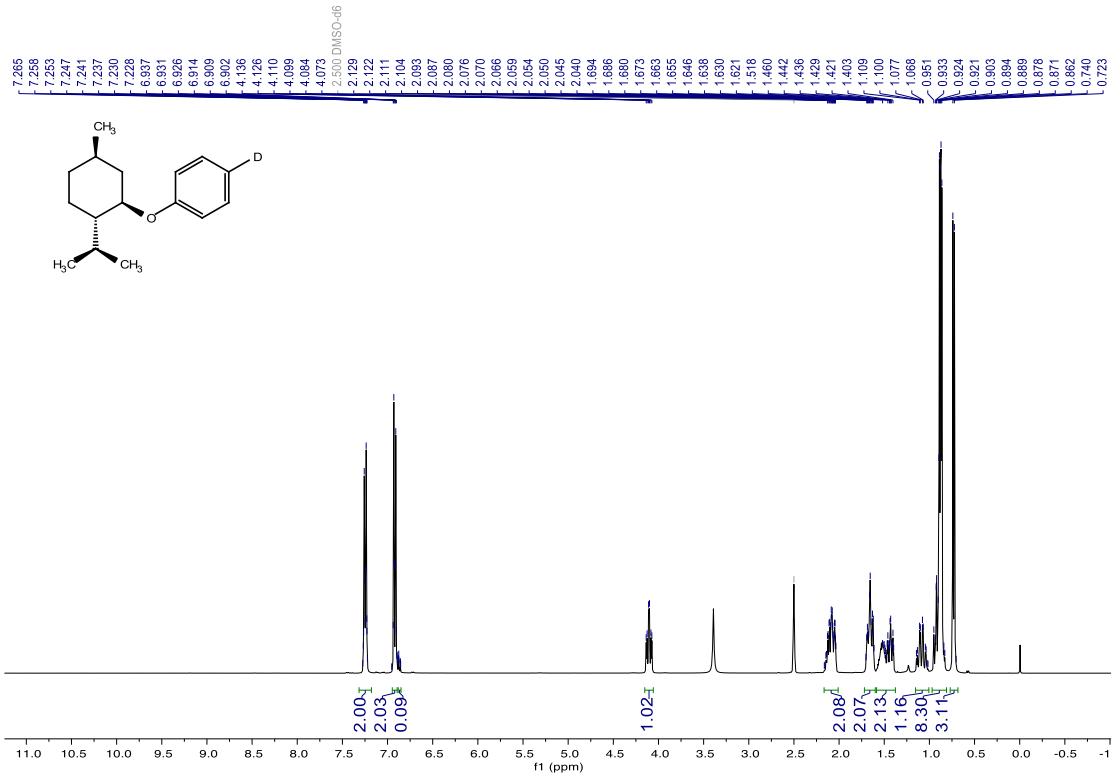

Figure S39 ^{1}H NMR of **29-[d]** in DMSO-d_6

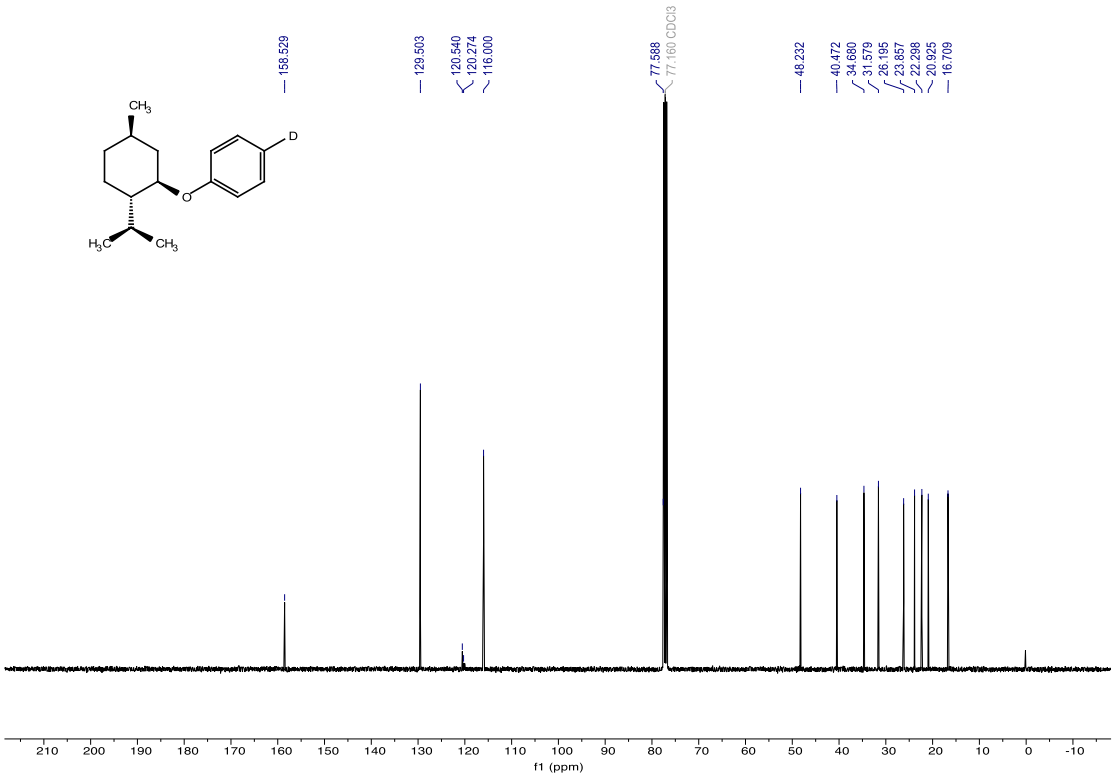

Figure S40 ^{13}C NMR of **28-[d]** in Chloroform-*d*

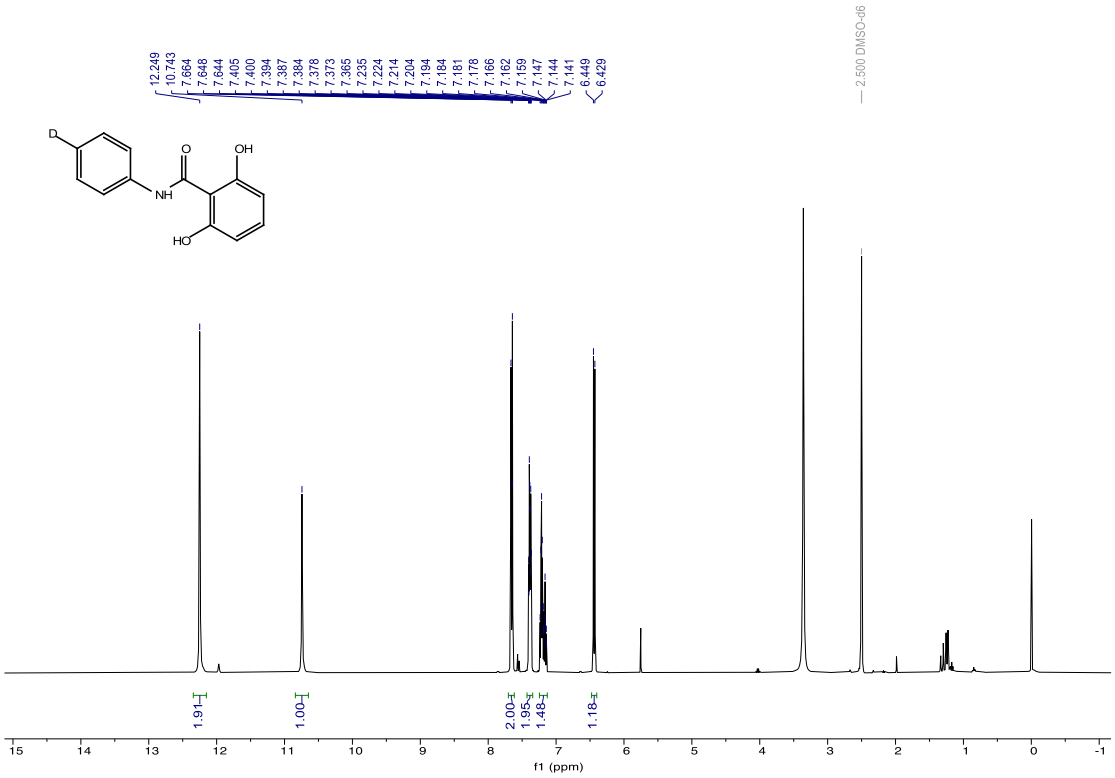

Figure S41 ^{1}H NMR of **30-[d]** in DMSO-d_6

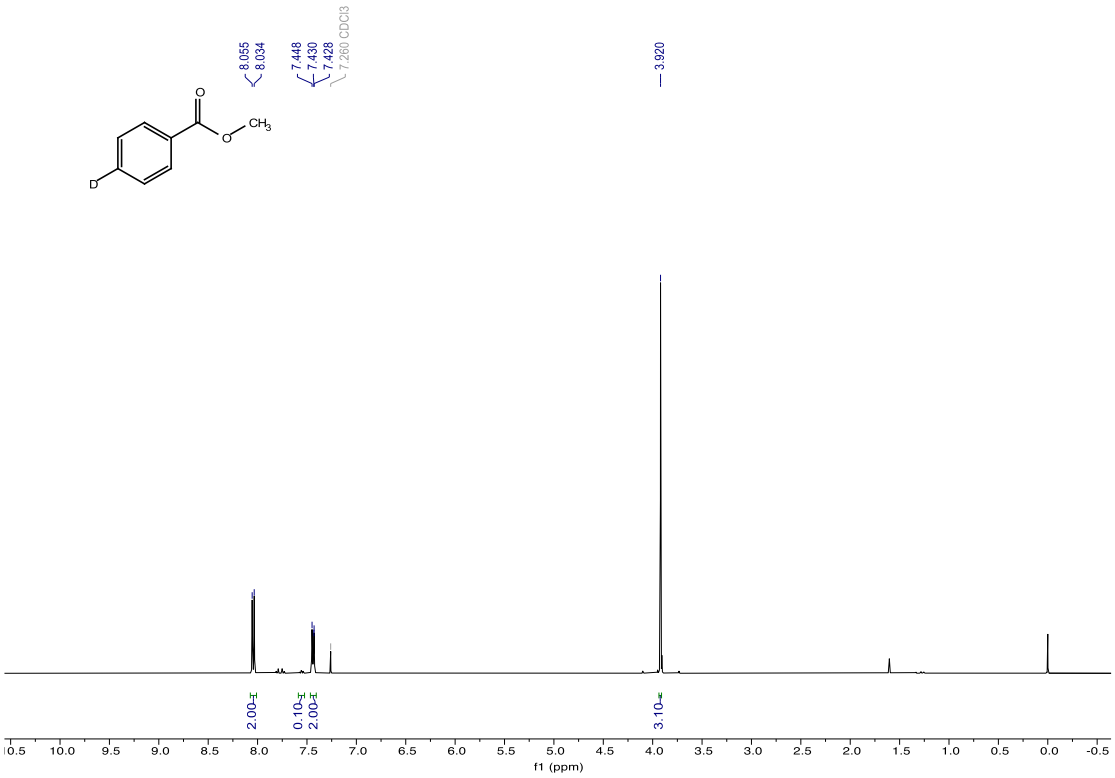

Figure S42 ^{1}H NMR of **1-[d]-I** in Chloroform-*d*

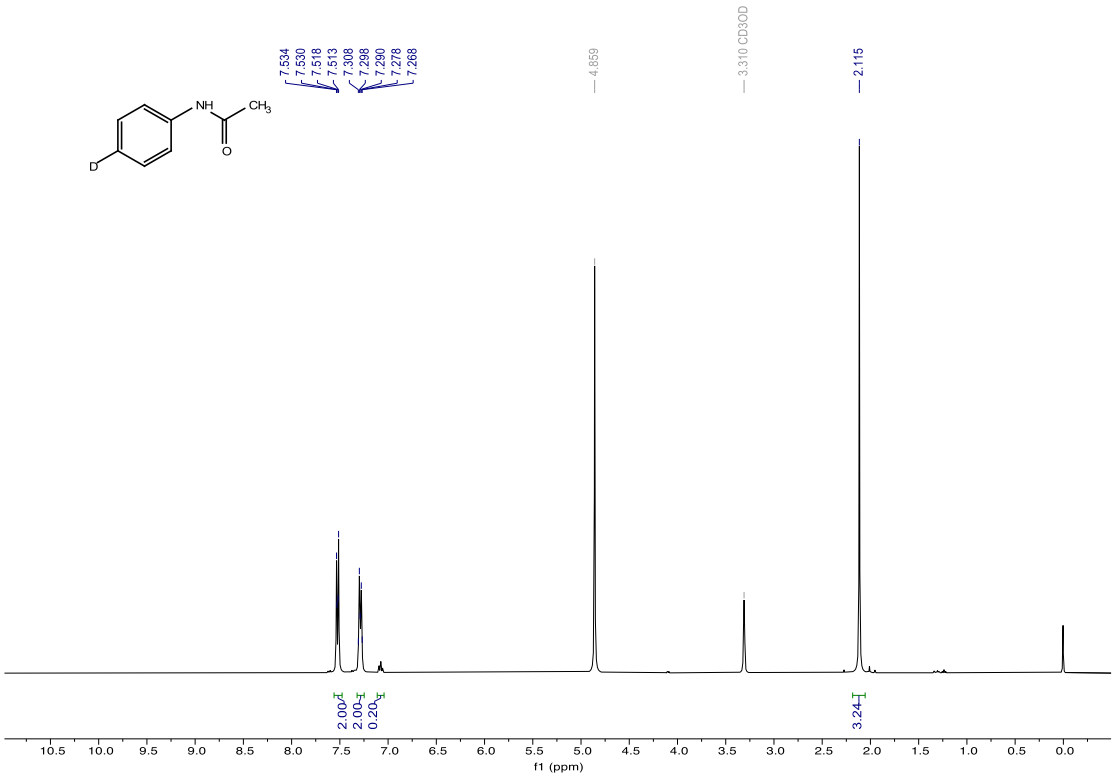

Figure S43 ^{1}H NMR of **9-[d]-I** in CD_3OD-d_4

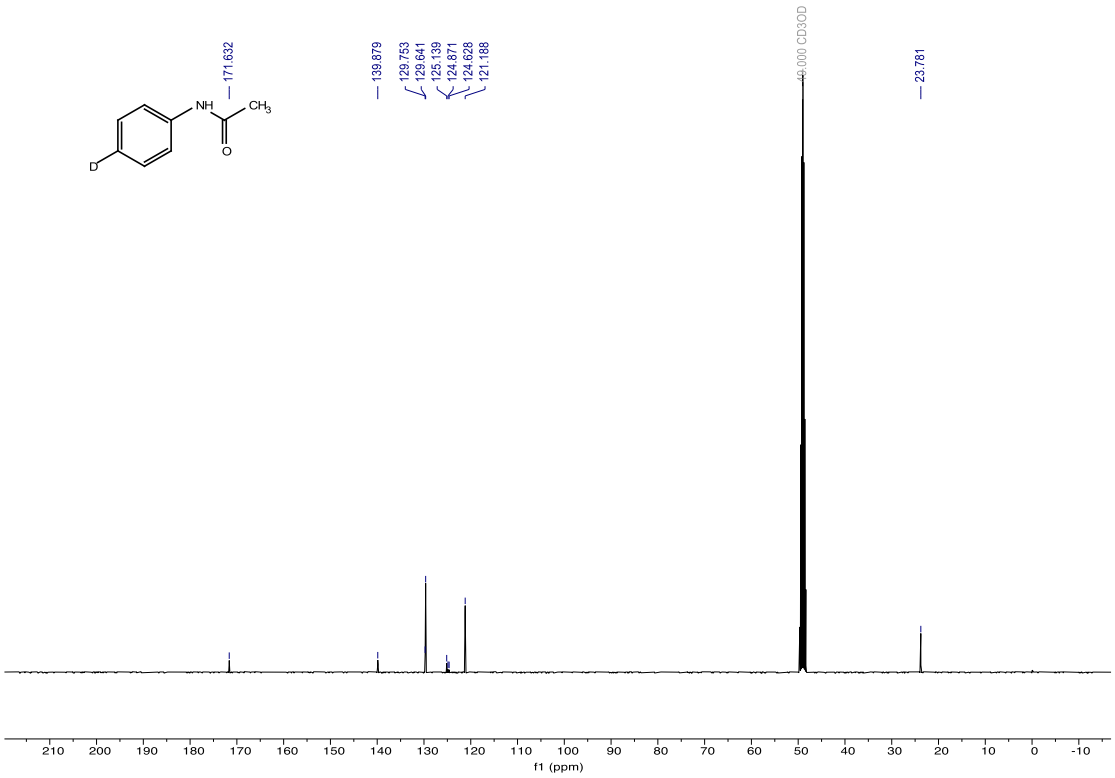

Figure S44 ^{13}C NMR of **9-[d]-I** in CD_3OD-d_4

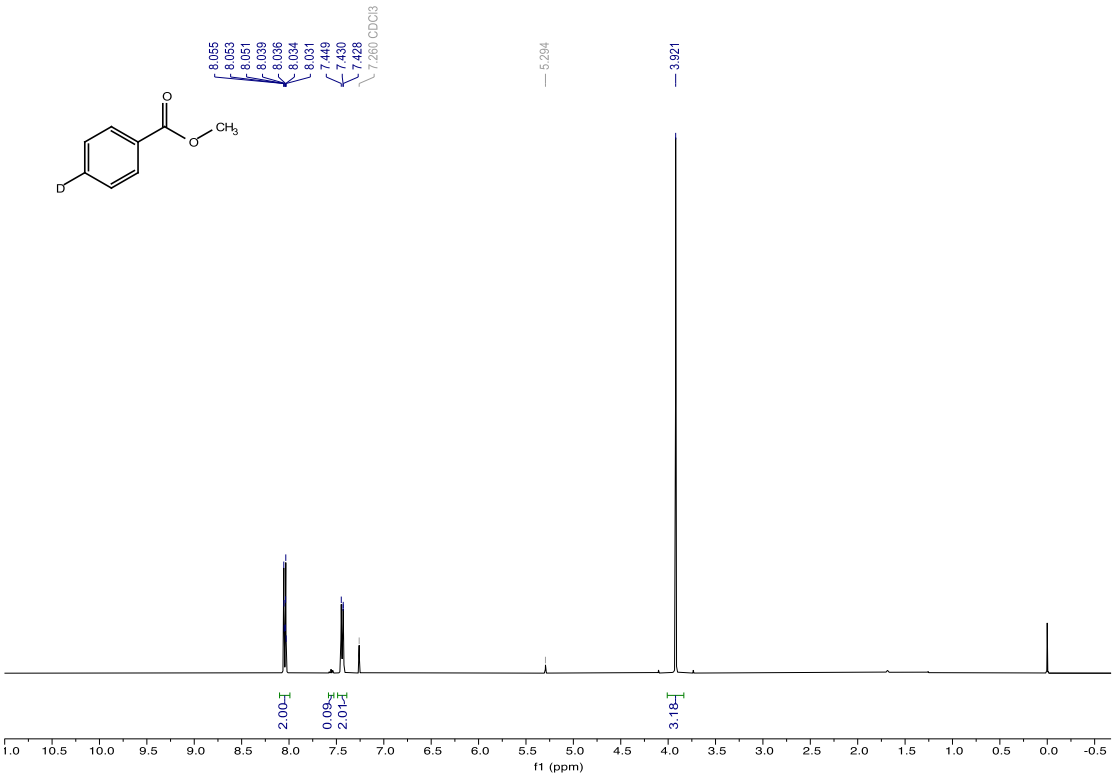

Figure S45 ^{1}H NMR of **1-[d]-Cl** in Chloroform-*d*

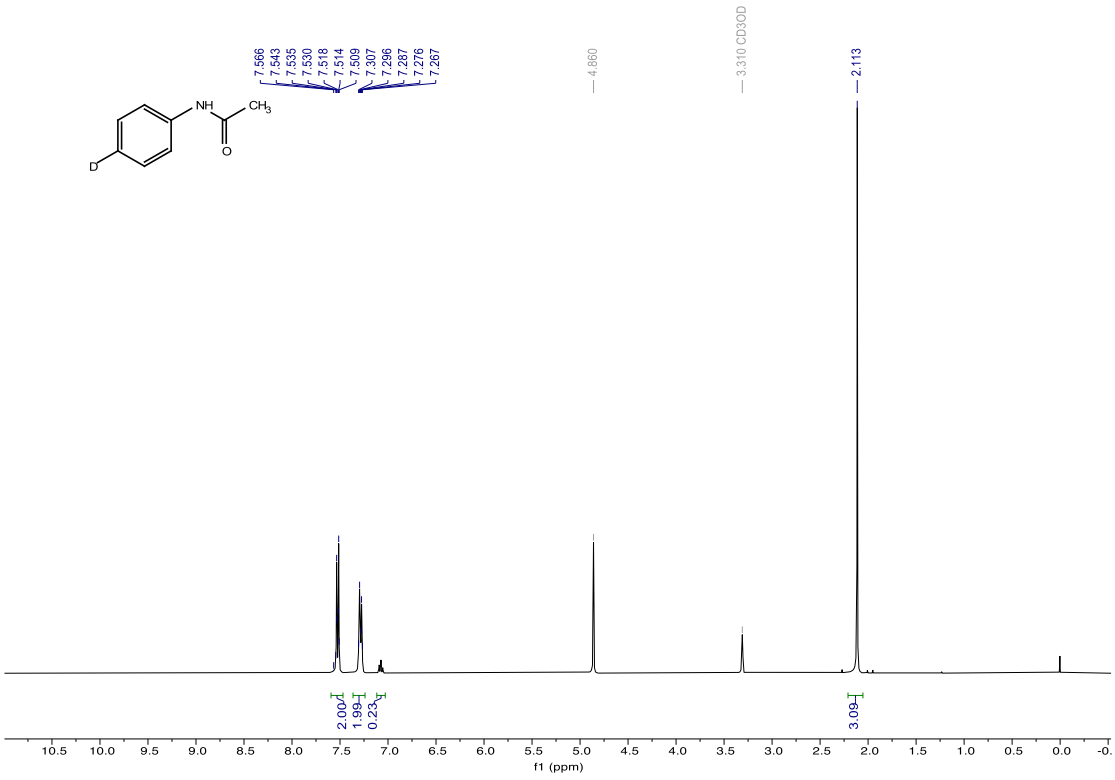

Figure S46 ^{1}H NMR of **9-[d]-Cl** in CD_3OD-d_4

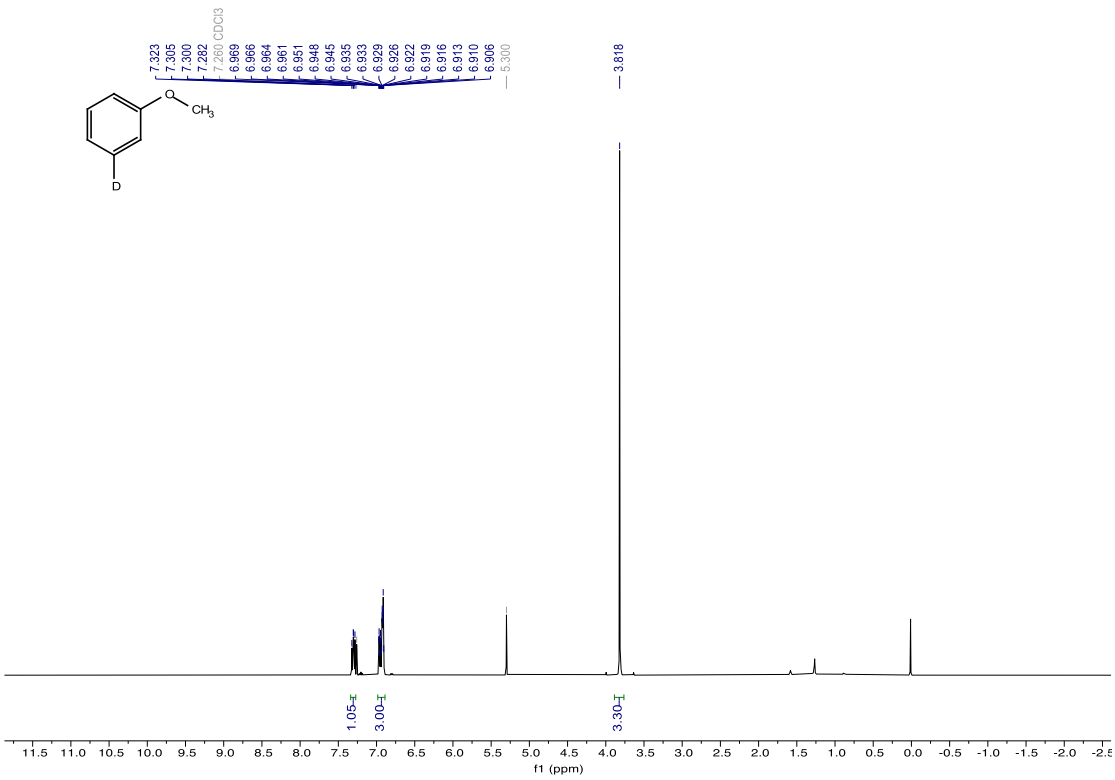

Figure S47 ^{1}H NMR of **11-[d]-Cl** in Chloroform-*d*

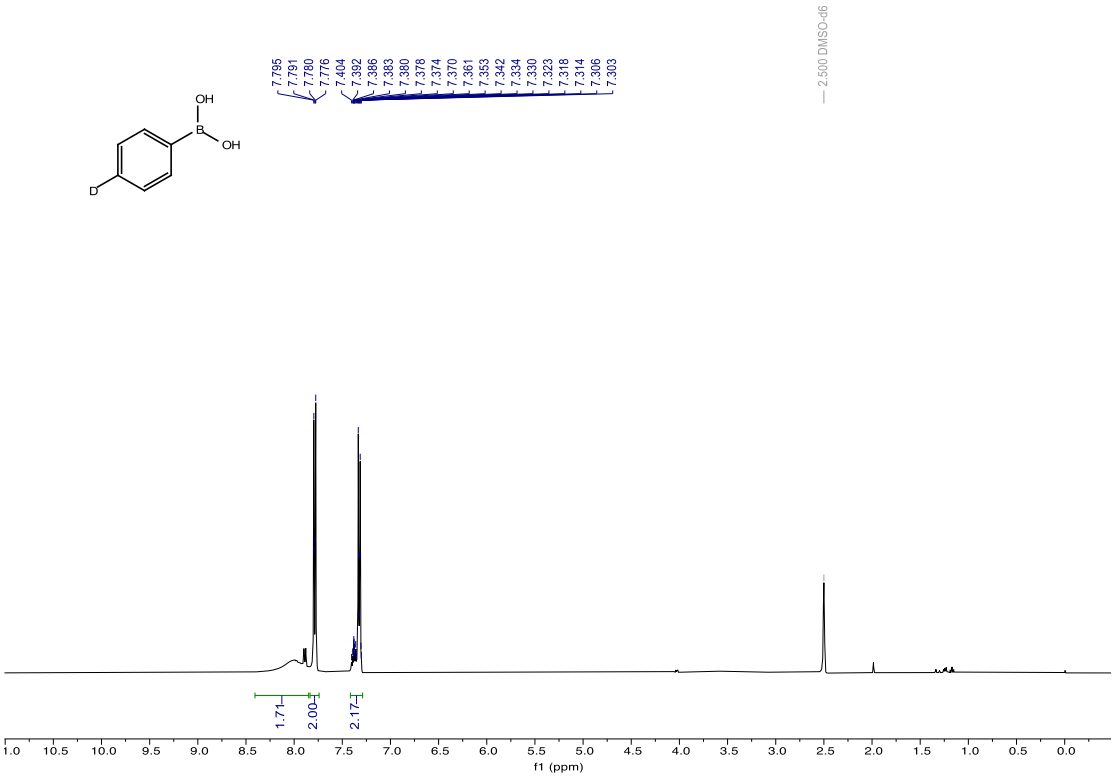

Figure S48 ^{1}H NMR of **31-[d]-Cl** in DMSO-d_6

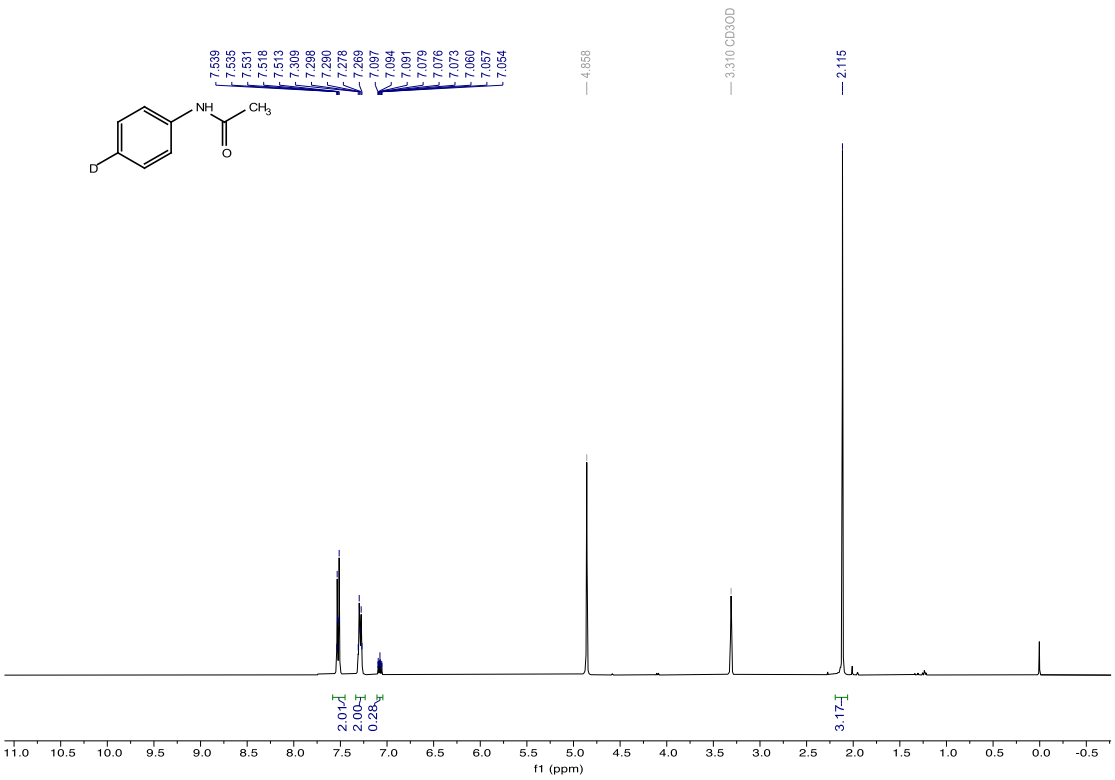

Figure S49 ^{1}H NMR of **9-[d]-OFs** in CD_3OD-d_4

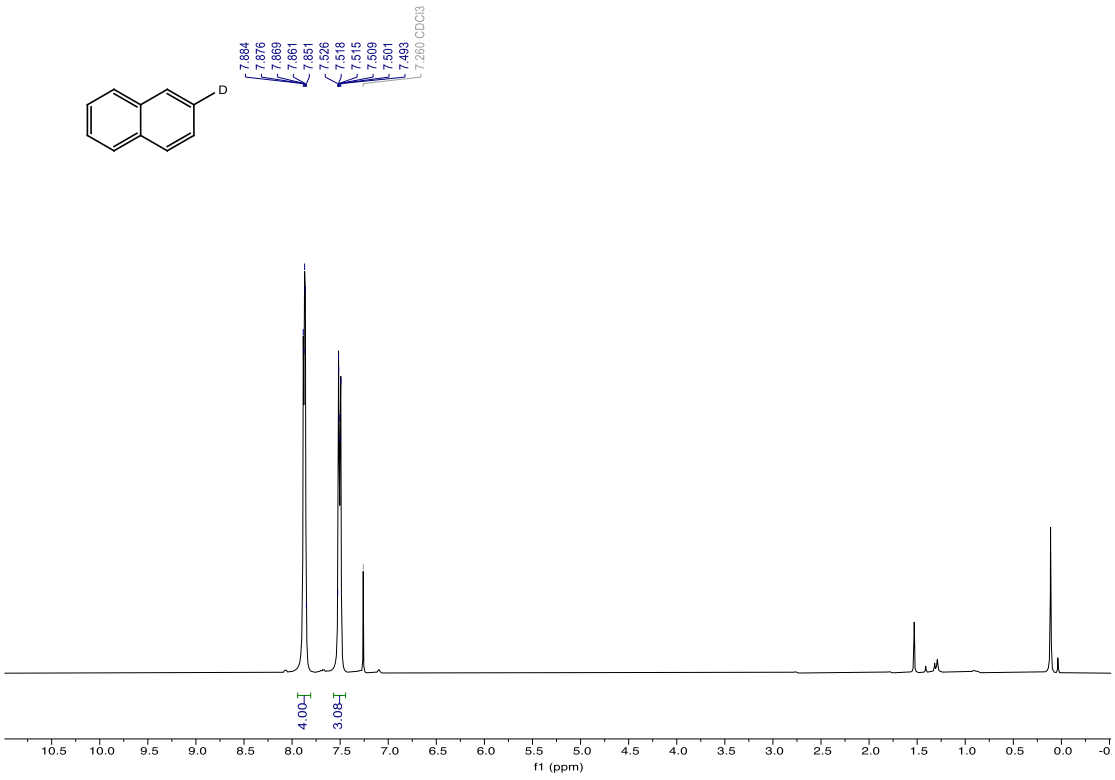

Figure S50 ^{1}H NMR of **14-[d]-OFs** in Chloroform-*d*

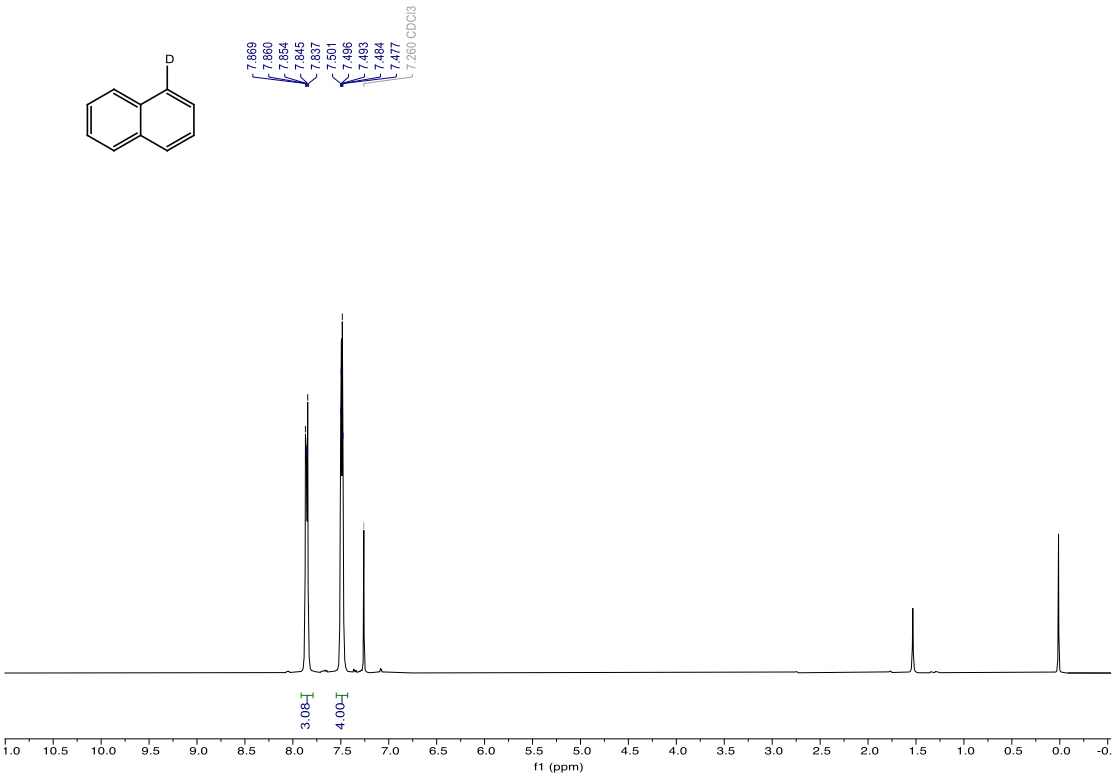

Figure S51 ^{1}H NMR of **15-[d]-OFs** in Chloroform-*d*

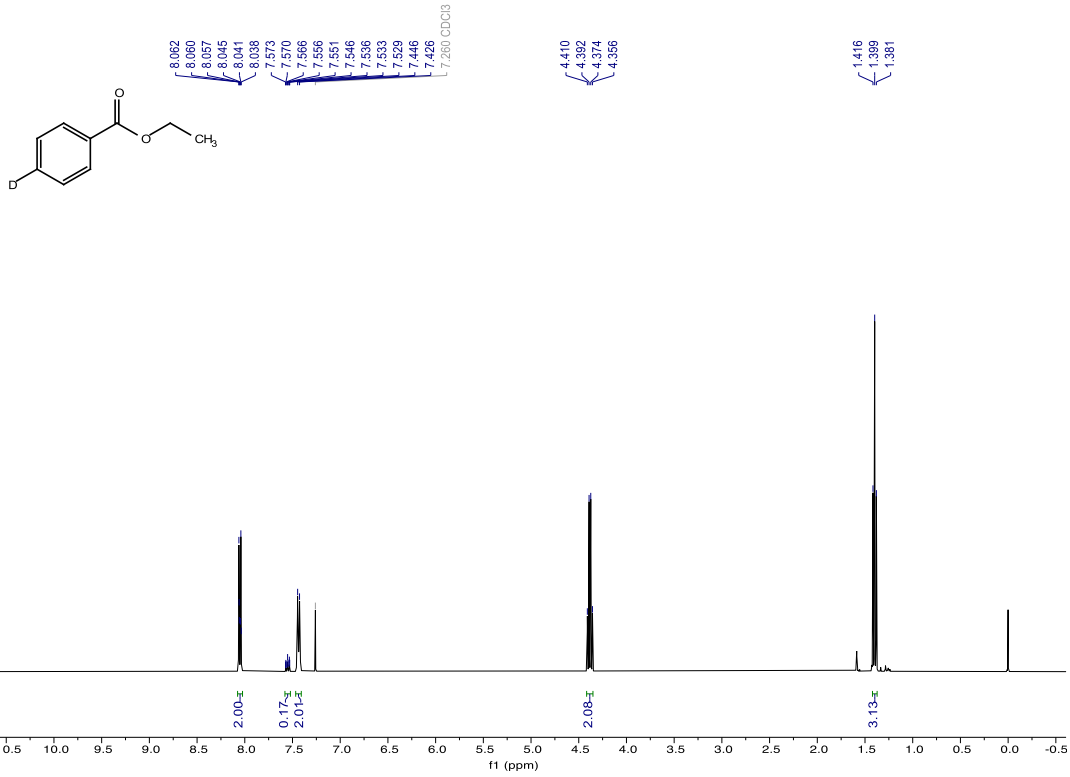

Figure S52 ^{1}H NMR of **32-[d]-OFs** in Chloroform-*d*

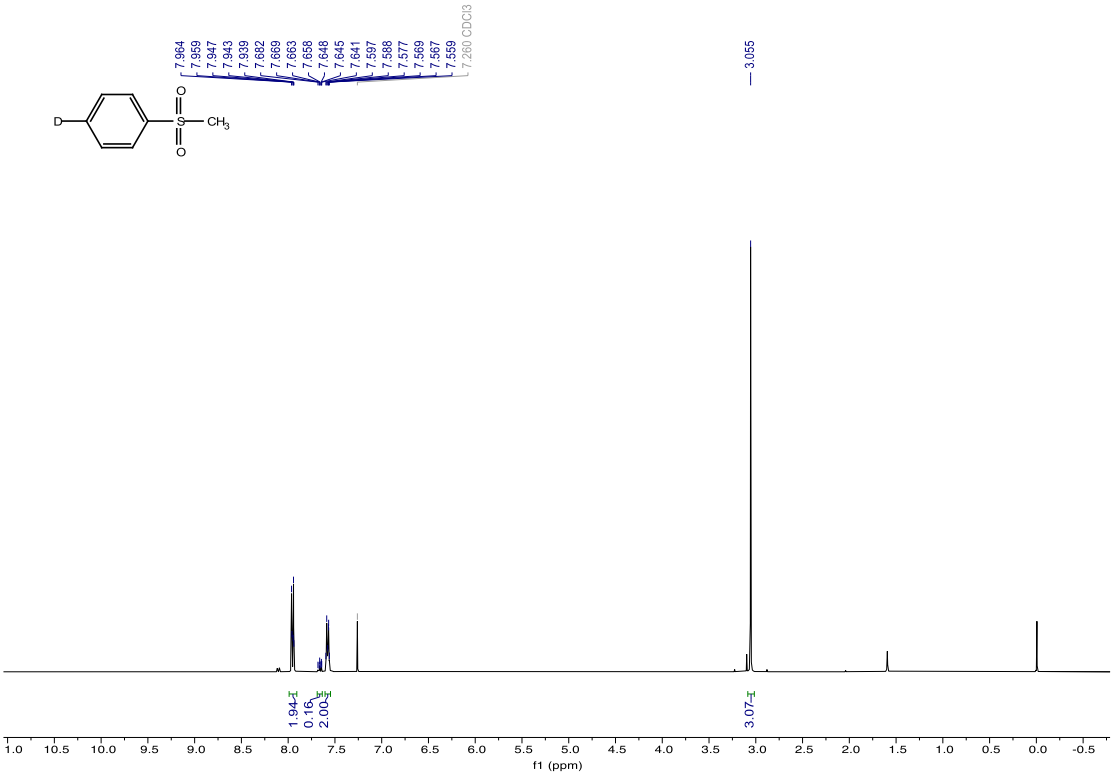

Figure S53 ^{1}H NMR of **33-[d]-OFs** in Chloroform-*d*

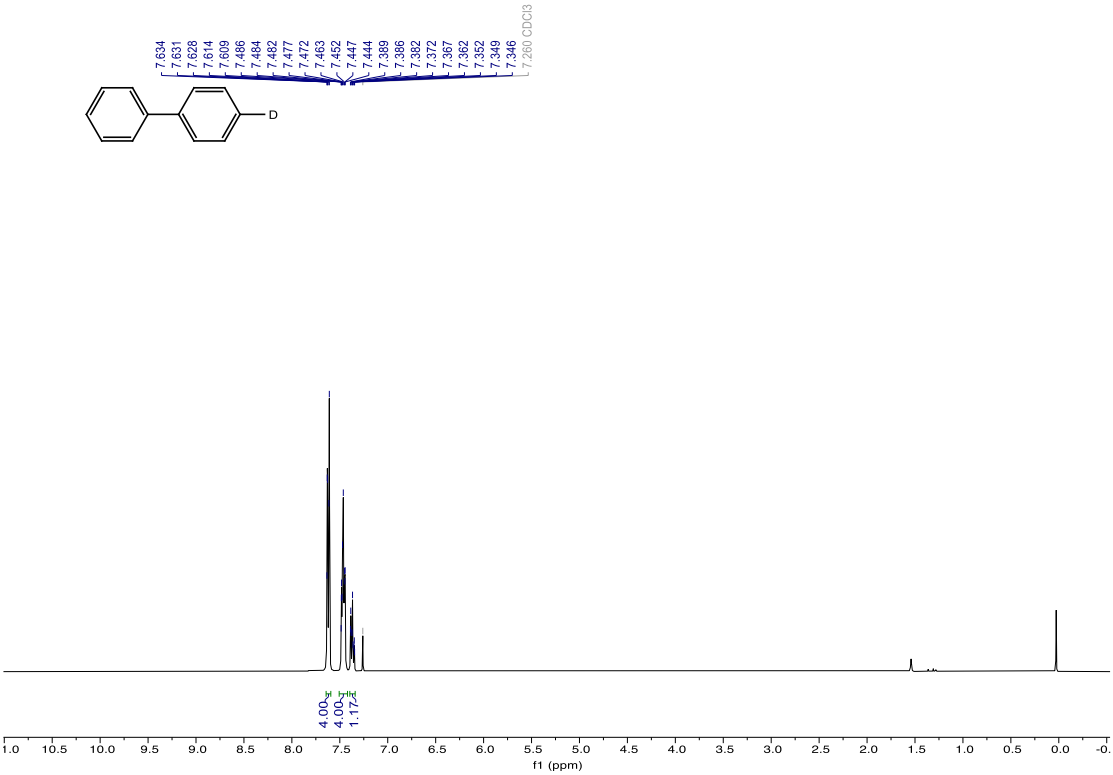

Figure S54 ^{1}H NMR of **34-[d]-OFs** in Chloroform-*d*

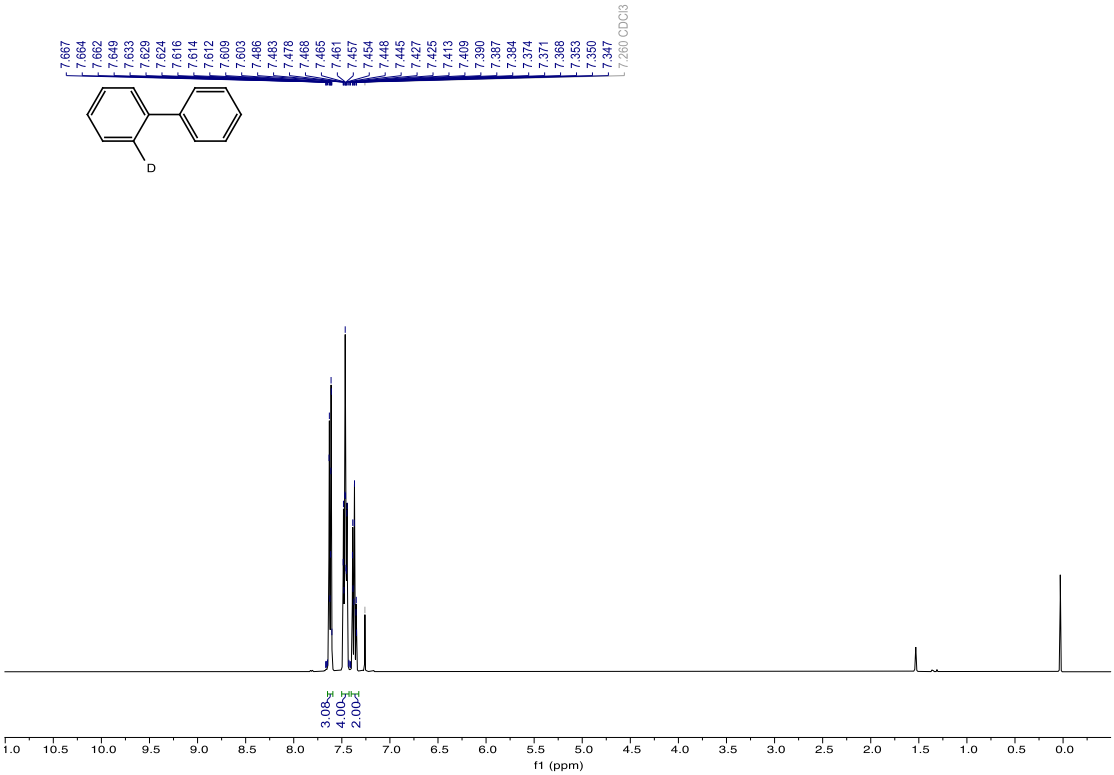

Figure S55 ^{1}H NMR of **35-[d]-OFs** in Chloroform-*d*