Electronic Supplementary Information for Dalton Transactions

Supplementary Information

For

Synthesis and Reactivity of a C_3-Symmetric Trinuclear Zinc(II) Hydroxide Catalyst Efficient at Phosphate Diester Transesterification

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Preparation of (4-*tert*-butyl-2-methyl-phenoxy)-acetic acid ethyl ester (8). Following a previously published method for the preparation of tris(3,5-di-tert-butyl-2-ethoxycarbonylmethoxyphenyl) methane,[1, 2] in a Schlenk flask under argon 1.0 g (6.1 mmol) of 2-methyl-4-tert-butylphenol was dissolved in dry acetone and 1.22 g (7.3 mmol) of ethylbromoacetate and 7.94 g (24.37 mmol) of Cs_2CO_3 were added. The mixture was refluxed for 12-15 hours and then cooled to room temperature. The acetone was removed under vacuum and the solids dissolved in diethyl ether. Solid $MgSO_4$ was added and the insoluble salts and drying agent were filtered off. The ether was removed from the filterate to give 1.3 g (87%) of the product as a colorless oil, which was pure enough for further modification. ^{1}H NMR (CD_3CN): δ = 1.3 (s, 9H, Ar-C(C*H*$_3$)$_3$), 1.31 (t, ^3J(H,H) = 7.2 Hz, 3H, $CO_2CH_2CH_3$), 2.31 (s, 3H, Ar-C*H*$_3$), 4.27 (q, ^3J(H,H) = 7.2 Hz, 2H, $CO_2CH_2CH_3$), 4.62 (s, 2H, Ar-O-C*H*$_2$CO$_2$Et), 6.65 (d, ^3J(H,H) = 8.7 Hz, 1H, Ar-*H*), 7.14 (dd, ^3J(H,H) = 8.6 Hz, ^4J(H,H) = 2.4 Hz, 1H, Ar-*H*), 7.19 (d, ^4J(H,H) = 2.6 Hz, 1H, Ar-*H*). Anal. Calcd. for **8** ($C_{15}H_{22}O_3$): C, 71.97; H, 8.86. Found: C, 71.85; H, 8.71.

Preparation of 2-(4-tert-butyl-2-methyl-phenoxy)ethanol (9). A dry diethylether solution of **8** (2 g, 7.99 mmol) was added dropwise over 30 min with an addition funnel to a slurry of $LiAlH_4$ (0.61 g, 15.98 mmol) in 100 ml dry diethyl ether cooled to 0°C. The mixture was then warmed to room temperature and stirred for 12-15 hours. The excess reductant was destroyed with 1 M HCl (100 ml). The ether layer was separated and further extracted with 1 M HCl (2 X 100 ml) and brine (100 ml). The

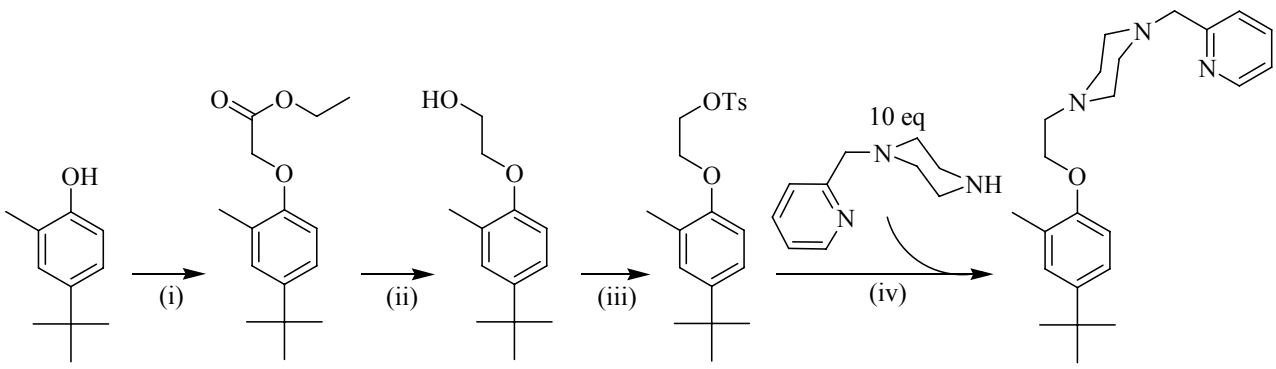
ether was then dried with $MgSO_4$. After filtration of the drying agent, the ether was removed to give 1.5 g (90%) of colorless oil. ^{1}H NMR (CD_3CN): δ = 1.4 (s, 9H, Ar-C(C*H*$_3$)$_3$), 2.39 (s, 3H, Ar-C*H*$_3$), 3.9 (t, ^{3}*J*(H,H) = 5.9 Hz, 2H, ArOC*H*$_2$), 4.3 (t, ^{3}*J*(H,H) = 5.9 Hz, 2H, ArOCH$_2$C*H*$_2$), 6.84 (d, ^{3}*J*(H,H) = 8.3 Hz, 1H, Ar-*H*), 7.28 (dd, ^{3}*J*(H,H) = 8.4 Hz, ^{4}*J*(H,H) = 2.5 Hz, 1H, Ar-*H*), 7.32 (d, ^{4}*J*(H,H) = 2.2 Hz, 1H, Ar-*H*). ^{13}C NMR (CD_3CN): δ = 16.6 (Ar-*C*H$_3$), 31.7 (Ar-C(*C*H$_3$)$_3$), 34.2 (Ar-*C*(CH$_3$)$_3$), 42.3 (Ar-O-*C*H$_2$CH$_2$), 68.4 (Ar-O-CH$_2$*C*H$_2$), 111.2, 123.4, 126.7, 128.3, 143.9, 154.3 (Ar). Anal. Calcd. for **9** ($C_{13}H_{20}O_2$): C, 74.96; H, 9.68. Found: C, 74.49; H, 9.38.

Preparation of toluene-4-sulfonic acid-2-(4-tert-butyl-2-methyl-phenoxy)-ethyl ester. (**10)**. In a dry flask, 1 g (4.8 mmol) of **9** was dissolved in 70 ml of dry pyridine and cooled to 0°C in an ice bath. A 1.4 g (7.3 mmol) portion of *p*-toluenesulfonylchloride was added and the reaction mixture was stirred for 2 hours at 0°C and then for 12-15 hours at room temperature. The pyridine was removed under vacuum and the sticky material dissolved in 100 ml methylene chloride and then extracted with 1 M-HCl (2 X 100 ml). The organic phase was then dried with $MgSO_4$, filtered and the solvent removed under reduced pressure. The residue was purified by silica gel column (ether/pentane, 9/1) to give the product as colorless oil (1.4 g, 80%).^{1}H NMR (CD_3CN): δ = 1.3 (s, 9H, Ar-C(C*H*$_3$)$_3$), 2.13 (s, 3H, Ar-C*H*$_3$), 2.45 (s, 3H, SO$_2$Ar-C*H*$_3$), 4.14 (m, 2H, ArOC*H*$_2$), 4.37 (m, 2H, ArOCH$_2$C*H*$_2$), 6.65 (d, ^{3}*J*(H,H) = 8.4 Hz, 1H, Ar-*H*), 7.13 (m, 2H, Ar-*H*), 7.34 (d, ^{3}*J*(H,H) = 8.5 Hz, 2H, SO$_2$Ar-*H*), 7.83 (d, ^{3}*J*(H,H) = 8.5 Hz, 2H, SO$_2$Ar-*H*).^{13}C NMR (CD_3CN): δ = 16.5 (Ar-*C*H$_3$), 21.8 (SO$_2$Ar-*C*H$_3$), 31.7 (Ar-C(*C*H$_3$)$_3$), 34.1 (Ar-*C*(CH$_3$)$_3$), 65.7 (Ar-O-*C*H$_2$CH$_2$), 68.6 (Ar-O-CH$_2$*C*H$_2$), 110.9, 123.4, 126.5, 128.1, 128.2, 130, 133.1, 143.9, 145.1, 154.1 (Ar). Anal. Calcd. for **10** ($C_{20}H_{26}SO_4$): C, 66.27; H, 7.23. Found: C, 66.70; H, 7.37.

Preparation of 1-(2-(4-tert-butyl-2-methylphenoxy)ethyl)-4-(pyridine-2-ylmethyl) piperazine. (11). To 1 g (2.82 mmol) of **10** dissolved in 50 ml dry acetonitrile was added 5 g (28.2 mmol) of 1-((2-pyridyl)methyl)piperazine and 1.2 g (11.3 mmol) of Na_2CO_3. The resulting mixture was refluxed for five days under an inert atmosphere. The solvent was then removed under vacuum and the remaining

material dissolved in diethyl ether. The organic layer was extracted with 0.1 M NaOH (2 X 100 ml), and then dried with Na_2SO_4, filtered, and the solvent removed to afford 0.9 g (90%) of brownish yellow oil. The excess 1-((2-pyridyl)methyl)piperazine was recovered from the aqueous phase by extraction with chloroform and removing the solvent under vacuum. ^{1}H NMR ($CDCl_3$): δ = 1.28 (s, 9H; Ar-C(CH_3)$_3$), 2.20 (s, 3H; Ar-CH_3), 2.58 (b, 4H; N-$CH_2$$CH_2$-N), 2.70 (b, 4H; N-$CH_2$$CH_2$-N), 2.86 (t, ^3J(H,H) = 6.0 Hz, 2H; Ar-O-$CH_2$$CH_2$-N), 3.67 (s, 2H; Py-$CH_2$), 4.10 (t, ^3J(H,H) = 5.7 Hz; 2H; Ar-O-CH_2), 6.72 (d, ^4J(H,H) = 8.4 Hz, 1H; Ar-*H*), 7.1-7.2 (m, 3H, Ar-*H*, Py-*H*), 7.40 (d, ^4J(H,H) = 7.8 Hz, 1H; Py-*H*), 7.64 (dt, ^3J(H,H) = 7.5 Hz, ^4J(H,H) = 1.8 Hz, 1H, Py-*H*), 8.55 (d, ^3J(H,H) = 4.8 Hz; 1H; Py-*H*). ^{13}C NMR ($CDCl_3$): δ = 16.7 (Ar-CH_3), 31.7 (Ar-C(CH_3)$_3$), 34.1 (Ar-C(CH_3)$_3$), 53.3 (Ar-O-$CH_2$$CH_2$-N-$CH_2$), 53.6 ($CH_2$-N-$CH_2$-Py), 57.4 (Ar-O-$CH_2$$CH_2$), 64.6 (N-$CH_2$-Py), 66.3 (Ar-O-$CH_2$), 110.6 (Ar), 122.2 (Py), 123.3 (Ar), 123.5 (Py), 126.1 (Ar), 128.0 (Ar), 136.5 (Py), 143.2 (Ar), 149.4 (Py), 154.7 (Ar), 158.4 (Py). Anal. Calcd. for **2-12**·½H_2O ($C_{23}H_{34}N_3O_{1.5}$): C, 73.37; H, 9.10; N, 11.16. Found: C, 73.49; H, 9.07; N, 11.16.

Scheme S1. Synthesis of Ligand.



Reagents and conditions: (i) 1.2 $BrCH_2COOEt$, 4 Cs_2CO_3, acetone, reflux (ii) 2 $LiAlH_4$, Et_2O (iii) 1.5 p-$CH_3C_6H_4SO_2Cl$, pyridine (iv) 4 Na_2CO_3, acetonitrile, 5 days reflux.

References

1 M. B. Dinger and M. J. Scott, *Eur. J. Org. Chem.*, 2000, 2467.

2 M. B. Dinger and M. J. Scott, *Inorg. Chem.*, 2001, **40**, 856.

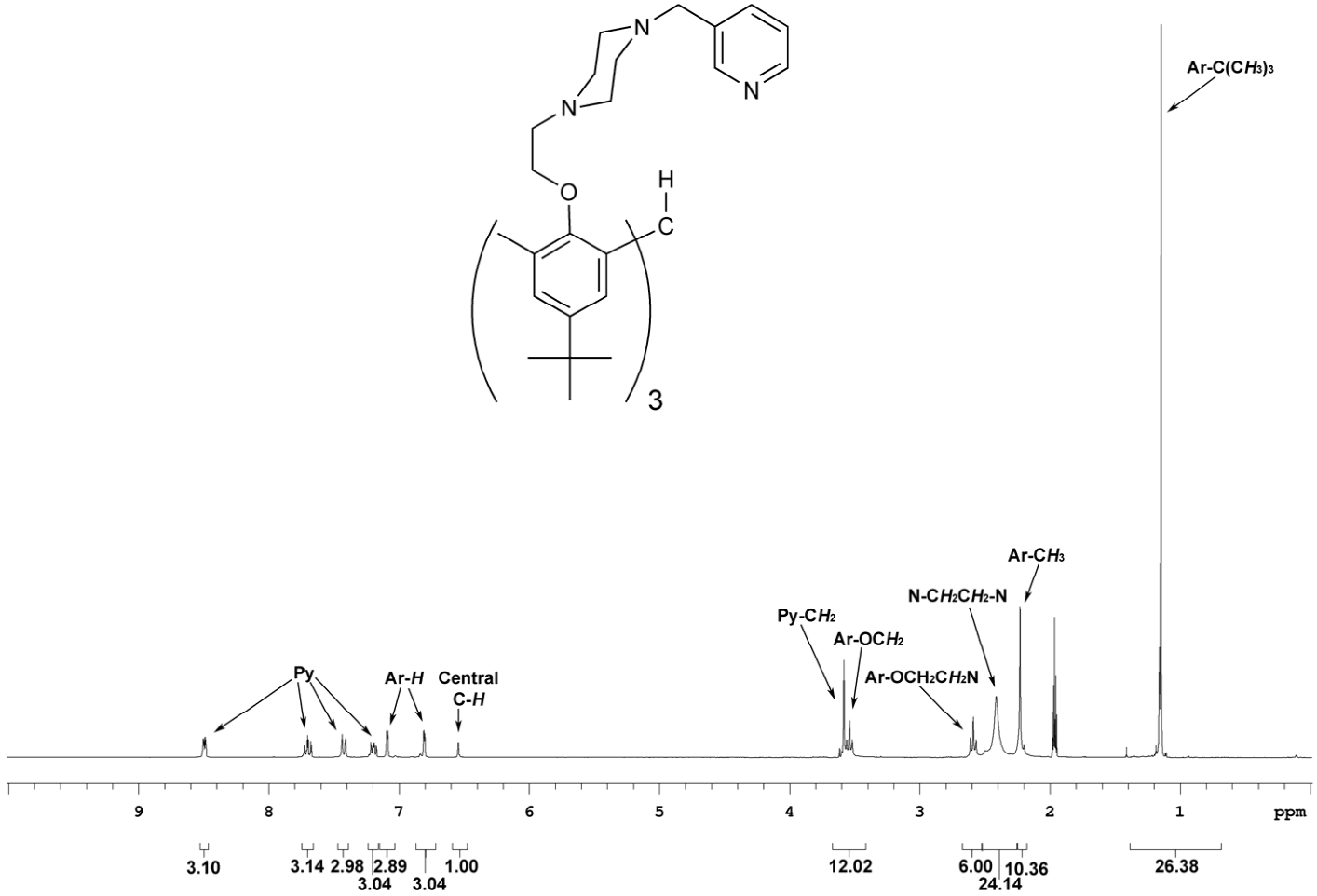


Figure S1. ^{1}H NMR spectra of **5** in CD_3CN.

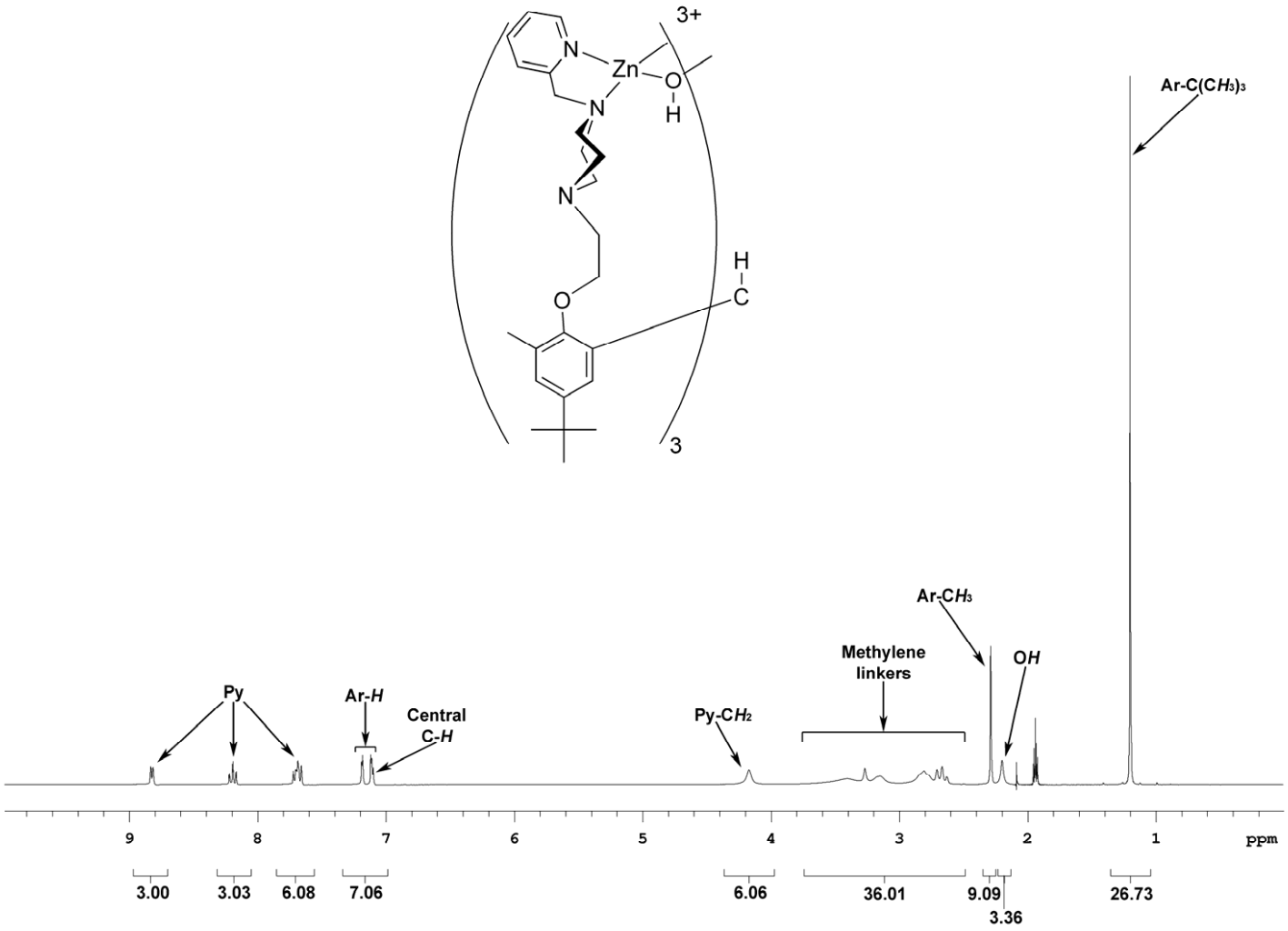


Figure S2. ^{1}H NMR spectra of **7** in CD_3CN.

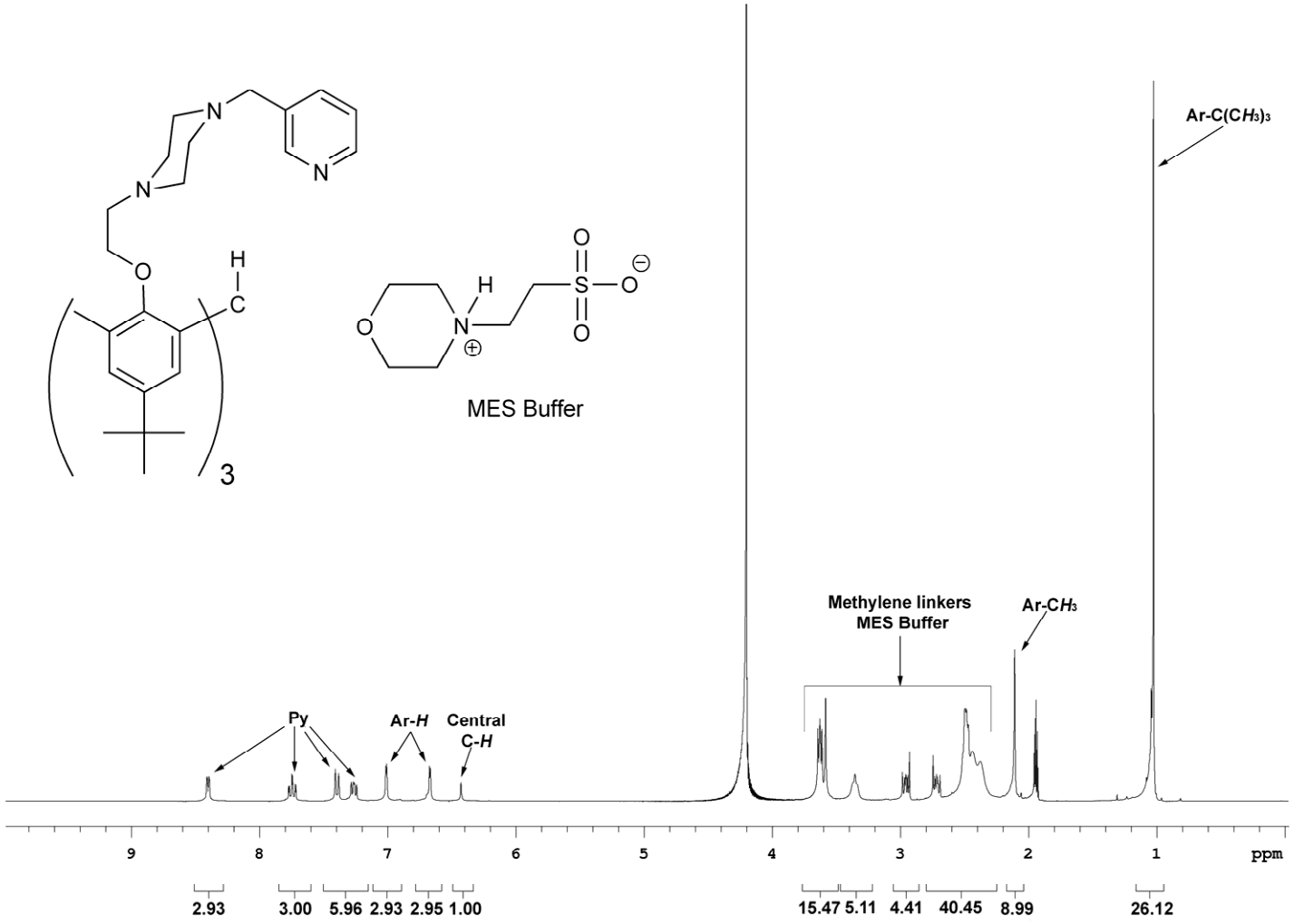


Figure S3. ^{1}H NMR spectra of **5** (7.5 mM) in MES buffer (22.5 mM) at pH=6.7 in 1:1 (CD_3CN : D_2O).

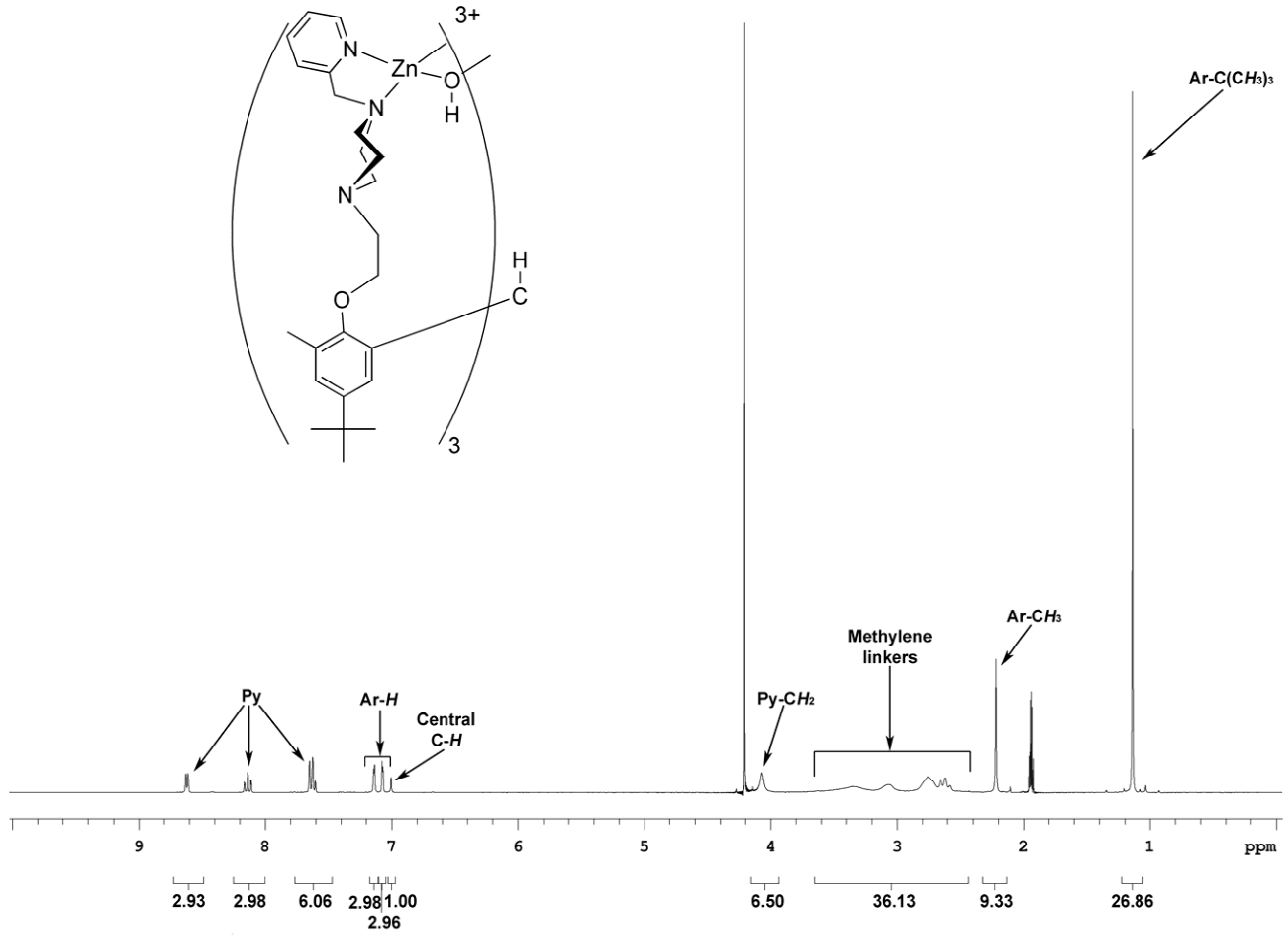


Figure S4. ^{1}H NMR spectra of **7** in 1:1 (CD_3CN : D_2O).

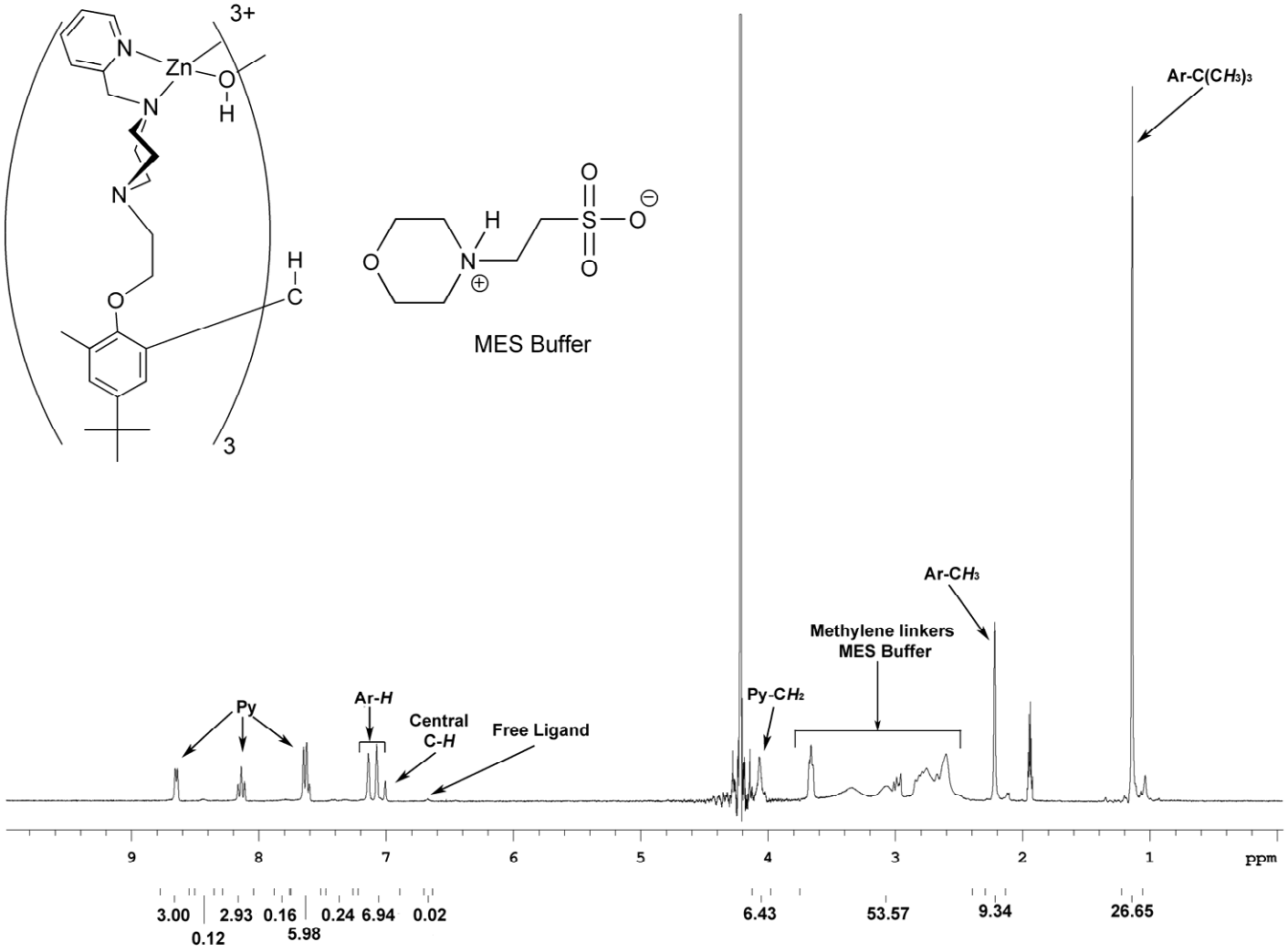


Figure S5. ^{1}H NMR spectra of the reaction mixture containing **7** (7.5 mM), MES buffer (22.5 mM) at pH=6.7 in 1:1 (CD_3CN : D_2O) after 30 min.

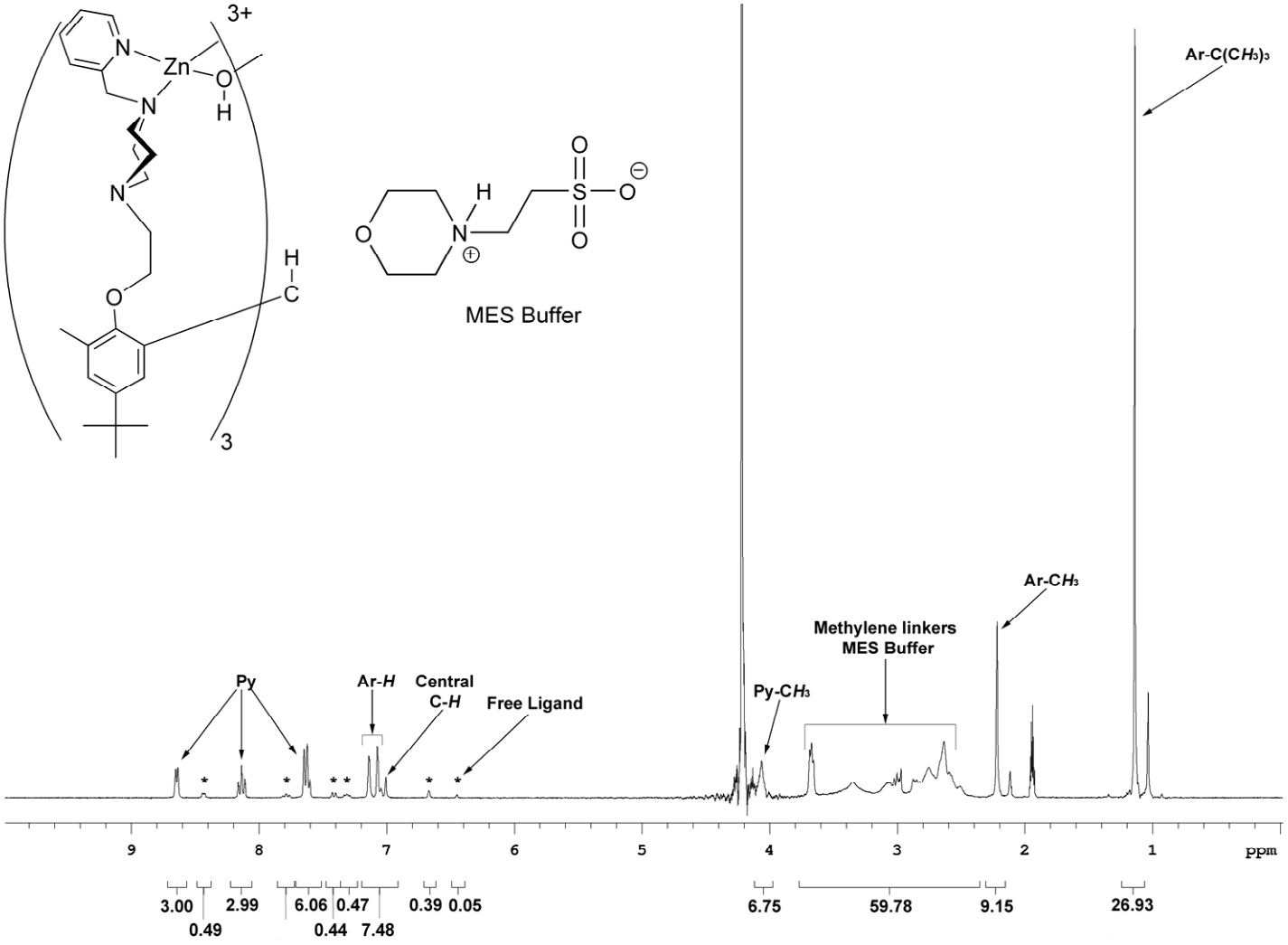


Figure S6. ^{1}H NMR spectra of the reaction mixture containing **7** (7.5 mM), MES buffer (22.5 mM) at pH=6.7 in 1:1 (CD_3CN : D_2O) after 24h.