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SUPPORTING INFORMATION

Click Reactions and Intramolecular Condensation on Azido-Adamantyl-Functionalized Tin Sulfide Clusters

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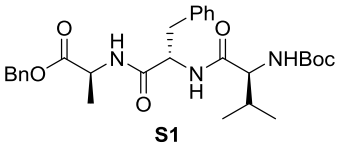
I. General Remarks

The reactions containing tin sulfide clusters were carried out under argon atmosphere with Schlenk techniques. Dry solvents were distilled prior to use and stored over 3 Å molecular sieve until use.

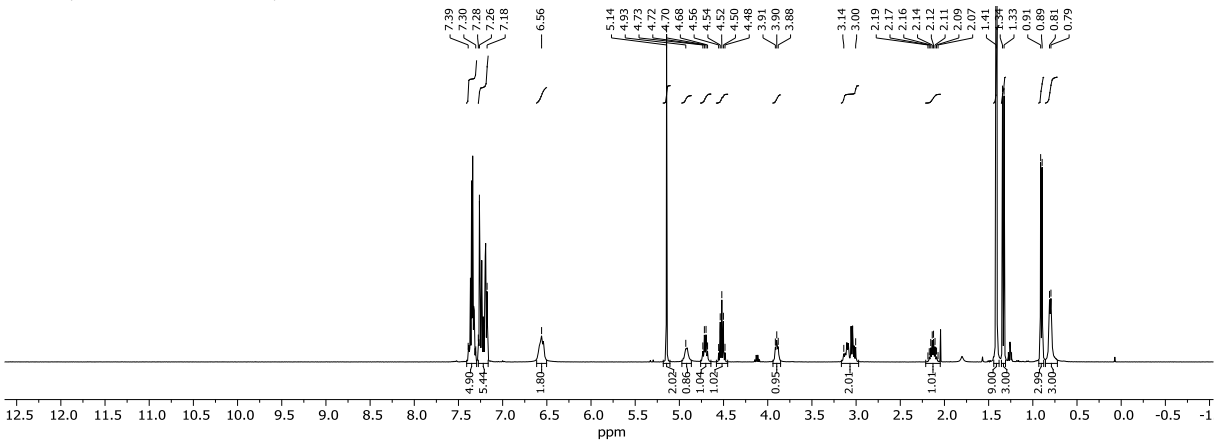
II. Synthesis

*Synthesis of Compound **S1**:*

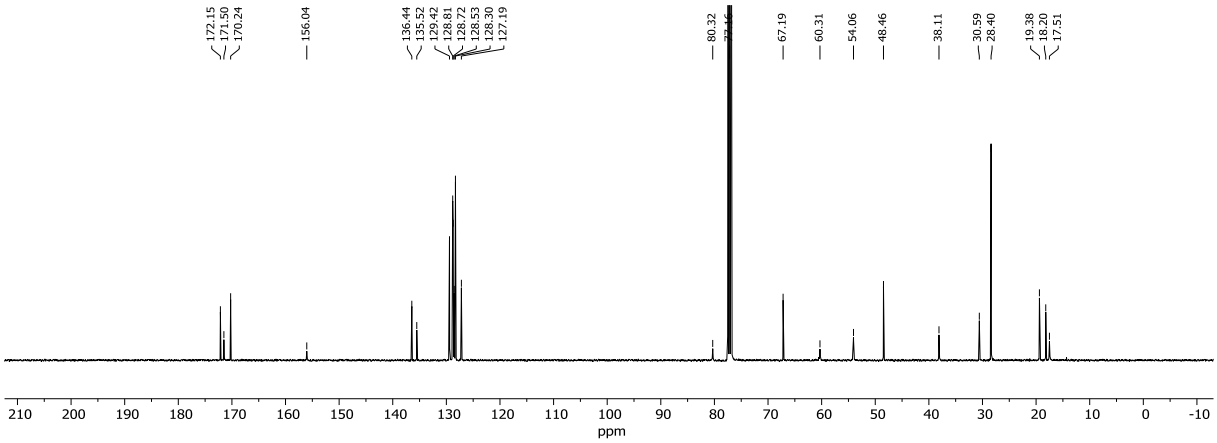


S1

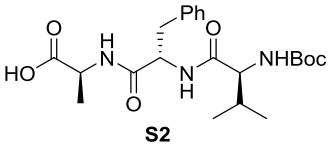
Tripeptide BnO-L-Ala-L-Phe-L-Val-Boc **S1** was synthesized according to liquid-phase peptide synthesis using following amounts: 1.73 g (8.00 mmol) BnO-L-Ala-H • HCl, 2.33 g (8.80 mmol) HO-L-Phe-Boc, and 1.91 g (8.80 mmol) HO-L-Val-Boc. Coupling sequences were performed by using 1.69 g (8.80 mmol) EDC • HCl, 1.35 g (8.80 mmol) HOBt, 1.22 mL (8.80 mmol) Et_3N, and 50 mL CH_2Cl_2. Boc deprotections were realized using 16 mL (64.0 mmol) 8 M HCl in dioxane. After column chromatography (10 CH_2Cl_2/1 MeOH) 3.54 g (6.73 mmol, 84%) of a colorless solid were obtained.
Yield: 3.54 g (6.73 mmol, 84%).
R_f (10 CH_2Cl_2/1 MeOH) = 0.88.
^{1}H-NMR (400 MHz, $CDCl_3$): δ/ppm = 7.41 – 7.29 (m, 5H), 7.27 – 7.16 (m, 5H), 6.56 (s, 2H), 5.14 (s, 2H), 4.93 (s, 1H), 4.71 (q, J = 6.9 Hz, 1H), 4.52 (p, J = 7.2 Hz, 1H), 3.90 (d, J = 6.6 Hz, 1H), 3.17 – 2.97 (m, 2H), 2.12 (dp, J = 13.6, 6.8 Hz, 1H), 1.41 (s, 9H), 1.33 (d, J = 7.2 Hz, 3H), 0.90 (d, J = 6.8 Hz, 3H), 0.80 (d, J = 6.4 Hz, 3H).



^{13}C-NMR (101 MHz, $CDCl_3$): δ/ppm = 172.2, 171.5, 170.2, 156.0, 136.4, 135.5, 129.4 (2C), 128.8 (2C), 128.7 (2C), 128.5, 128.3 (2C), 127.2, 80.3, 67.2, 60.3, 54.1, 48.5, 38.1, 30.6, 28.4 (3C), 19.4, 18.2, 17.5.



*Synthesis of Compound **S2**:*

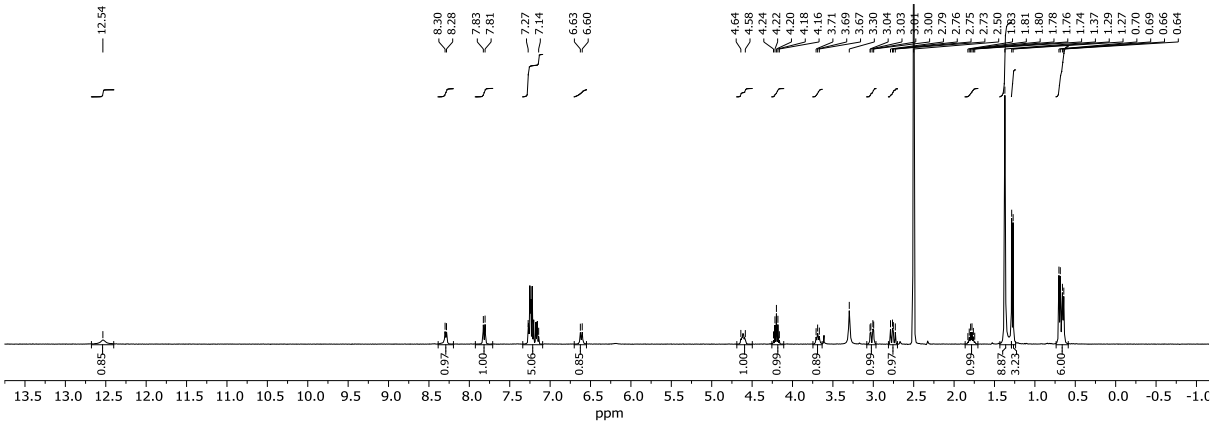


S2

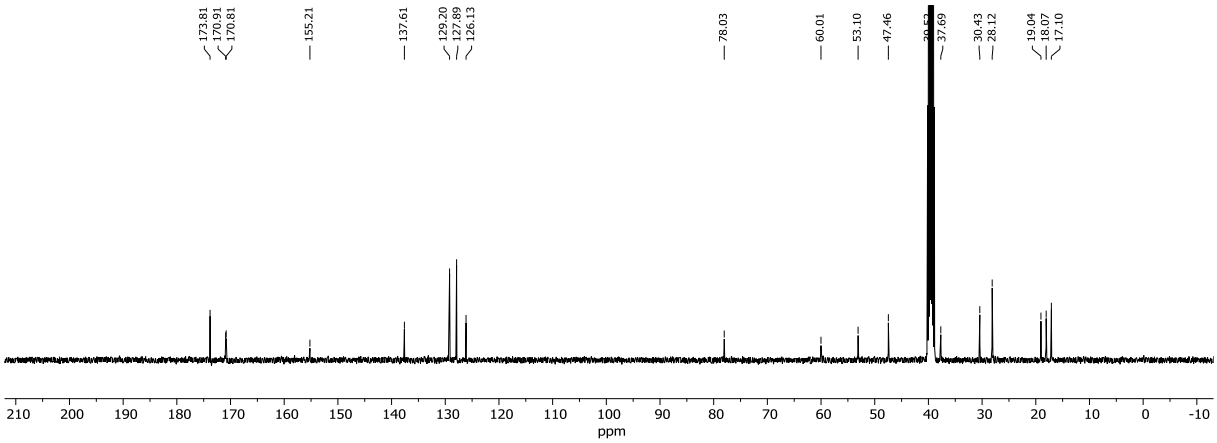
1.00 g (1.90 mmol) **S1** and 0.200 g (0.190 mmol) Pd/C (10%) were dissolved in 50 mL MeOH and stirred overnight at 25 °C under a hydrogen atmosphere. Pd/C was filtered off with Celite, and the mother liquor concentrated under reduced pressure. 0.812 g (1.86 mmol, 98%) of a colorless solid were obtained.

Yield: 0.812 g (1.86 mmol, 98%).

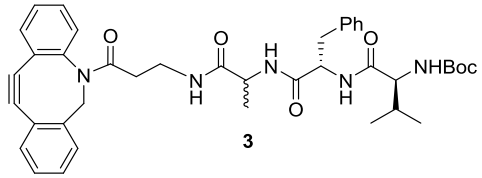
^{1}H-NMR (400 MHz, DMSO-d_6): δ/ppm = 12.54 (s, 1H), 8.29 (d, *J* = 7.1 Hz, 1H), 7.82 (d, *J* = 8.6 Hz, 1H), 7.21 (d, *J* = 52.0 Hz, 5H), 6.70 – 6.55 (m, 1H), 4.69 – 4.50 (m, 1H), 4.20 (p, *J* = 7.2 Hz, 1H), 3.75 – 3.63 (m, 1H), 3.02 (dd, *J* = 14.0, 4.1 Hz, 1H), 2.76 (dd, *J* = 14.0, 9.8 Hz, 1H), 1.79 (h, *J* = 6.7 Hz, 1H), 1.37 (s, 9H), 1.28 (d, *J* = 7.3 Hz, 3H), 0.67 (dd, *J* = 17.4, 6.7 Hz, 6H).



^{13}C-NMR (101 MHz, DMSO-d_6): δ/ppm = 173.8, 170.9, 170.8, 155.2, 137.6, 129.2 (2C), 127.9 (2C), 126.1, 78.0, 60.0, 53.1, 47.5, 37.7, 30.4, 28.1 (3C), 19.0, 18.1, 17.1.



*Synthesis of Compound **3**:*

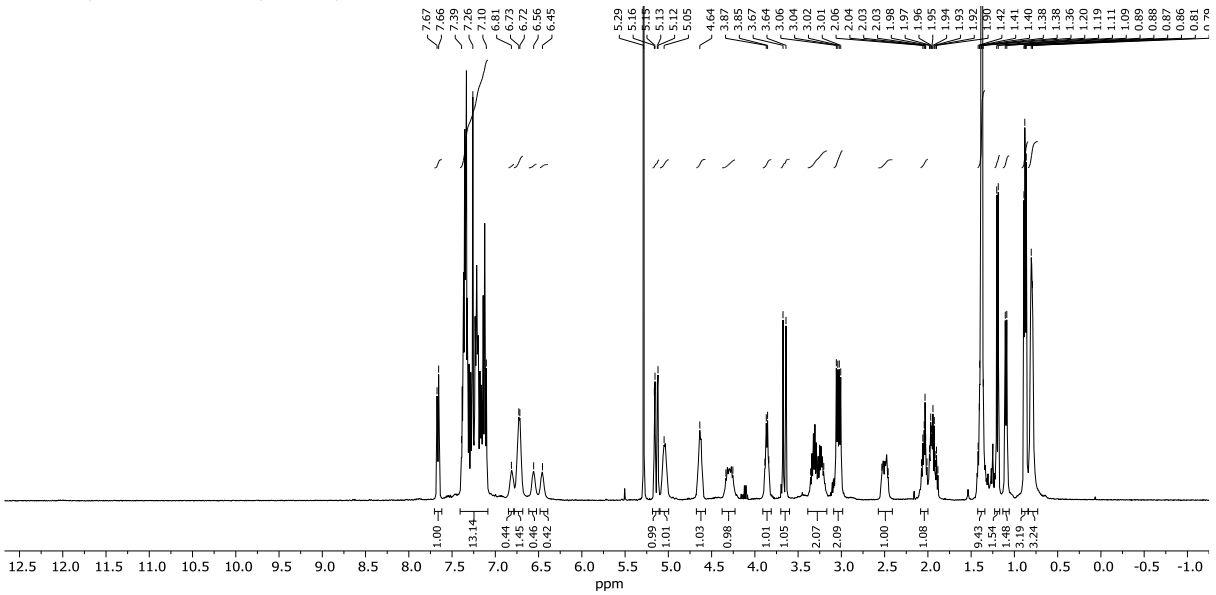


3

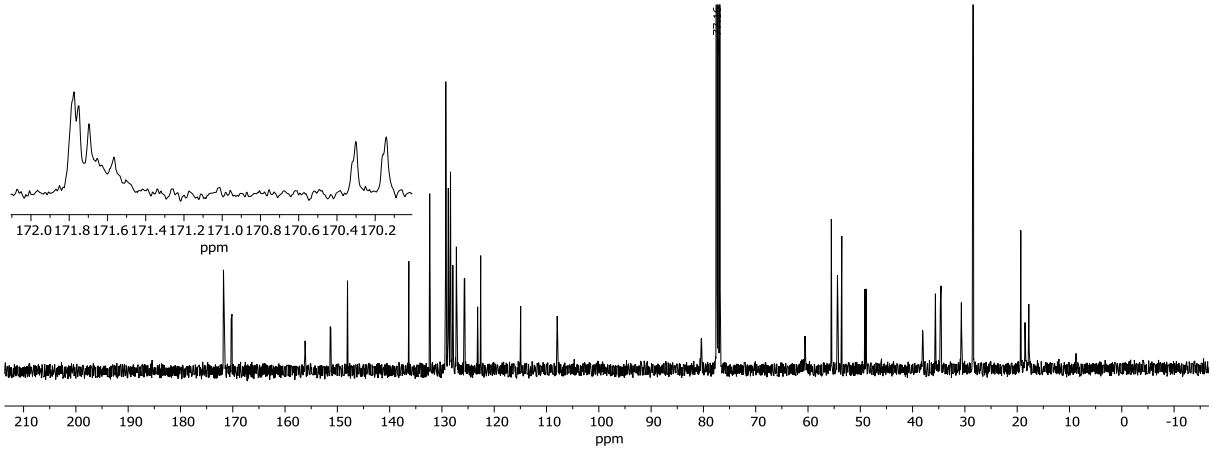
0.100 g (0.394 mmol) dibenzocyclooctyne-amine, 0.206 g (0.473 mmol) **S2**, 0.091 g (0.473 mmol) EDC • HCl, 0.073 g (0.473 mmol) HOBt, 0.062 mL (0.473 mmol) Et_3N, and 10 mL CH_2Cl_2 stirred over night at 25 °C. The reaction solution was concentrated and the crude product was purified by column chromatography (1 *n*-Hexane / 1 EtOAc →10 CH_2Cl_2/1 MeOH). 0.273 g (0.393 mmol, >99%) of a colorless solid were obtained. Note: As indicated for structure **3** the stereogenic center of alanine epimerizes under the employed conditions.

Yield: 0.273 g (0.393 mmol, >99%).

^{1}H-NMR (400 MHz, $CDCl_3$): δ/ppm = 7.66 (d, *J* = 7.3 Hz, 1H), 7.41 – 7.09 (m, 13H), 6.81 (br s, 0.5H), 6.75 – 6.68 (m, 1.5H), 6.56 (br s, 0.5H), 6.45 (br s, 0.5H), 5.14 (dd, *J* = 13.9, 3.0 Hz, 1H), 5.10 – 5.00 (m, 1H), 4.64 (s, 1H), 4.38 – 4.23 (m, 1H), 3.86 (q, *J* = 5.9 Hz, 1H), 3.66 (d, *J* = 13.8 Hz, 1H), 3.39 – 3.17 (m, 2H), 3.03 (dd, *J* = 13.6, 6.7 Hz, 2H), 2.50 (d, *J* = 29.3 Hz, 1H), 2.07 – 2.00 (m, 1H), 1.38 (d, *J* = 1.7 Hz, 9H), 1.20 (d, *J* = 7.0 Hz, 1.5 H), 1.10 (d, *J* = 7.0 Hz, 1.5H), 0.88 (dd, *J* = 6.8, 3.9 Hz, 3H), 0.83 – 0.76 (m, 3H).



The ^{13}C-NMR spectrum shows up to 10 signals which accord to different amid bonds. These signals are obtained as a result of the epimerization of the peptide during the synthesis, which inhibits proper assignment of the peaks.



*Synthesis of Compound **1**:*

0.086 g (0.0585 mmol, 1.0 eq) of compound **D** and 0.048 g (0.176 mmol, 3.0 eq) aza-dibenzocyclooctyne-amine **E** were dissolved in 1.5 mL CH_2Cl_2 respectively. The solutions were combined and stirred for 18 h at room temperature. The solvent was removed *in vacuo* and a light yellow powder was obtained.

^{119}Sn NMR (187 MHz, $CDCl_3$): δ/ppm = –80.

Due to very poor solubility and a presumably high mobility of the substituents we were not able to detect all three chemically different tin atoms, but the signal is shifted downfield with respect to the precursor (–103 ppm),[6] hence indicating that the reaction took place.

HRMS (ESI+): m/z = 1751.3503 $[M\text{-}Cl^-]^+$ (calc. for $[C_{76}H_{93}N_{14}O_4S_4Sn_3]^+$ (**1**$^+$) m/z = 1751.3468).

*Synthesis of Compound **2***:

0.049 g (0.0715 mmol, 3.0 eq) peptide substituted alkyne **3** were dissolved in 4.0 mL CH_2Cl_2 and added to 0.035 g (0.0238 mmol, 1.0 eq) of compound **D**. The solution was stirred at room temperature for 16 h. Afterwards the solvent was removed *in vacuo* and a light yellow powder was obtained.

^{119}Sn NMR (187 MHz, $CDCl_3$): δ/ppm = –63, –96.

HRMS (ESI+): m/z = 2820.9427 (calc. for $[C_{131}H_{172}N_{24}O_{15}S_4Sn_3]^+$ (**2**$^+$) m/z = 2820.9447).

III. Spectroscopy and spectrometry

NMR spectroscopy: ^{119}Sn NMR spectra of the substituted tin sulfide clusters were carried out using a Bruker Avance III at 298 K. Chemical shifts (δ) are given in ppm relative to the respective solvent residual peaks: $CDCl_3$ δ = 7.26 and 77.16 ppm; DMSO-d_6 δ =2.50 and 39.52 ppm.

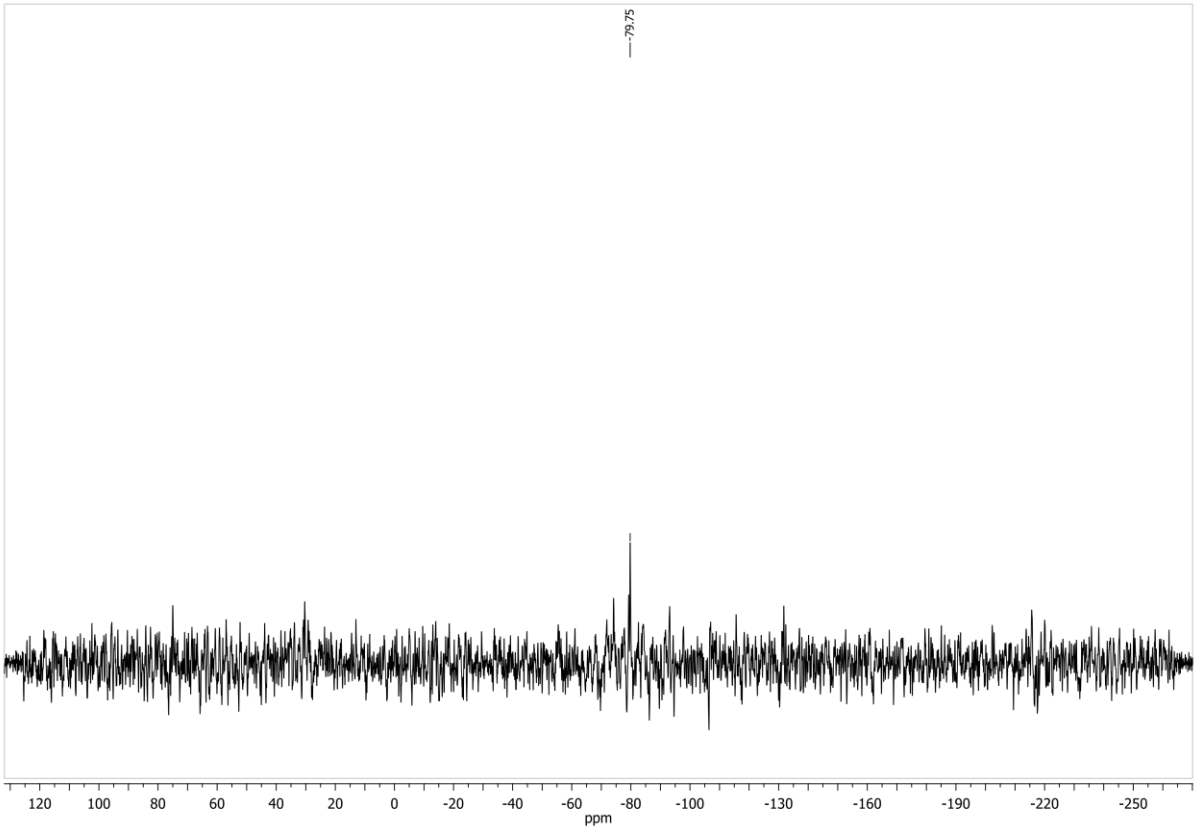


Figure S1. ^{119}Sn NMR spectrum of compound **1·Cl** in $CDCl_3$.

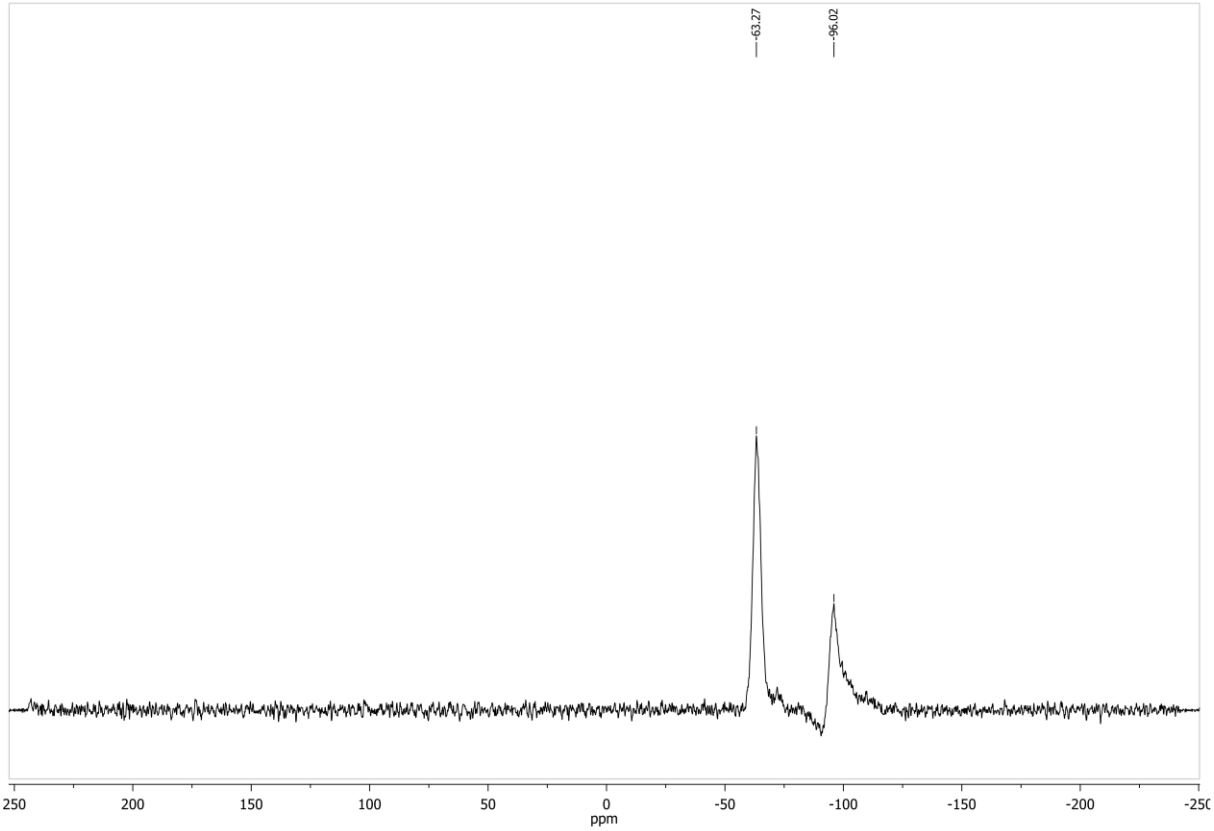


Figure S2. ^{119}Sn NMR spectrum of compound **2·Cl** in $CDCl_3$.

Mass spectrometry: ESI(+)-MS measurements were carried out using a LTQ-FT Ultra from Thermo Fischer Scientific with syringe pump infusion method.

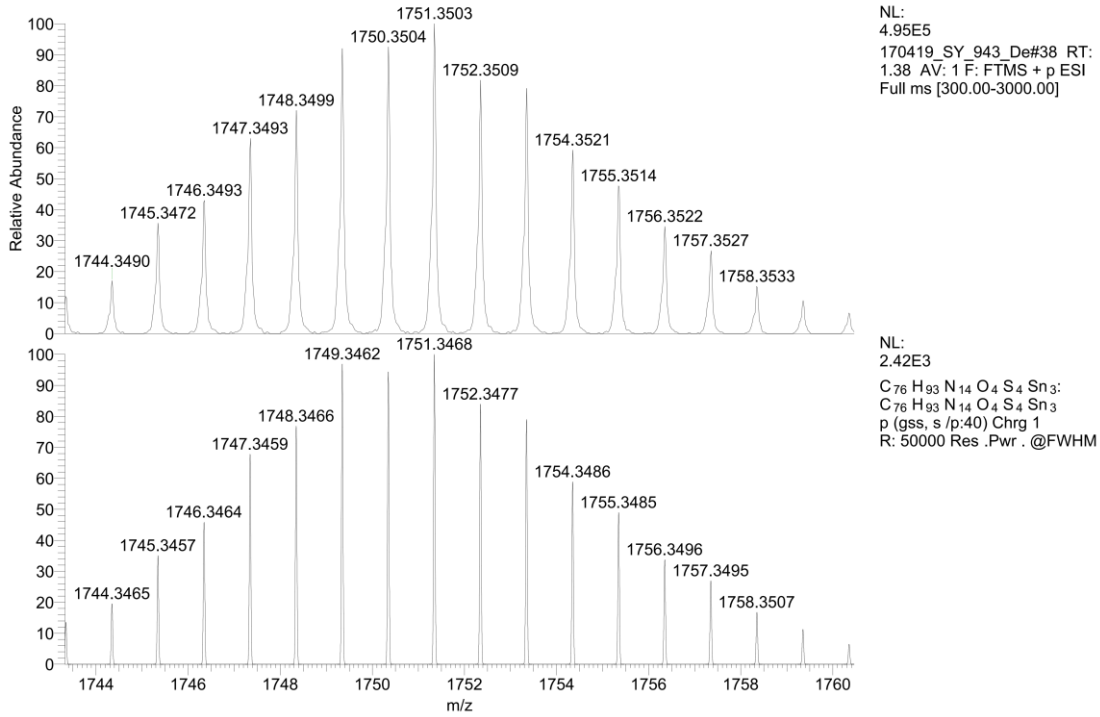


Figure S3. HRMS of the signal of **1**$^{+}$ with the sum formula $[C_{76}H_{93}N_{14}O_4S_4Sn_3]^+$.

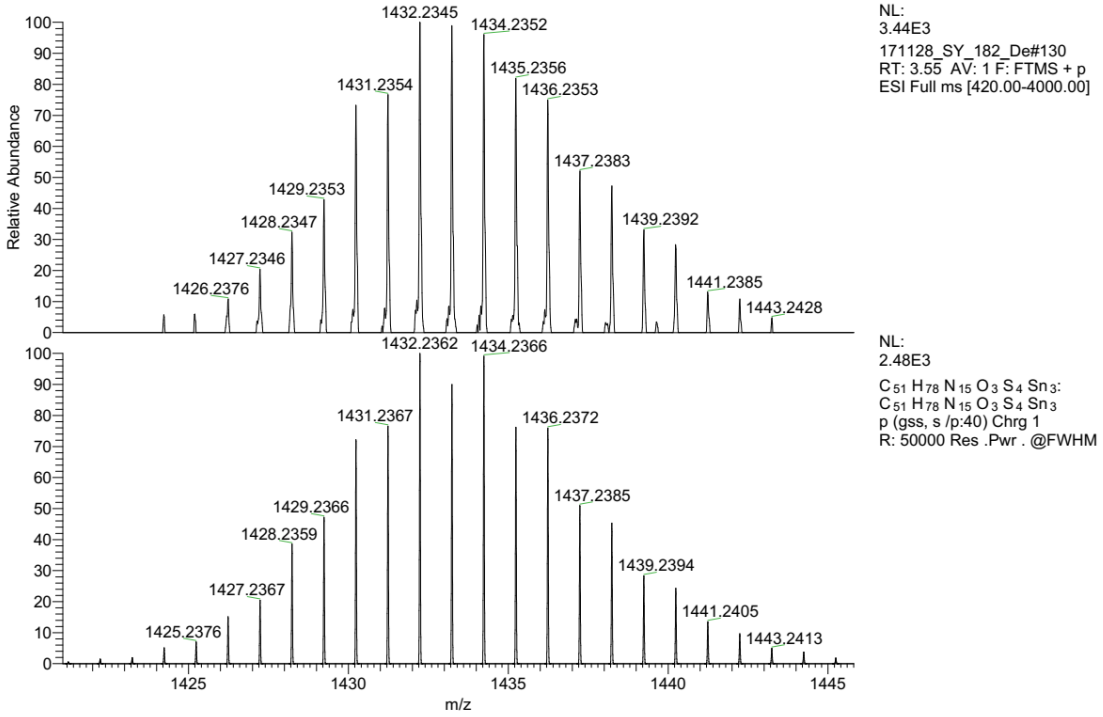


Figure S4. HRMS of the signal at 1432.2345 m/z corresponding to the sum formula $[C_{51}H_{78}N_{15}O_3S_4Sn_3]^+$.

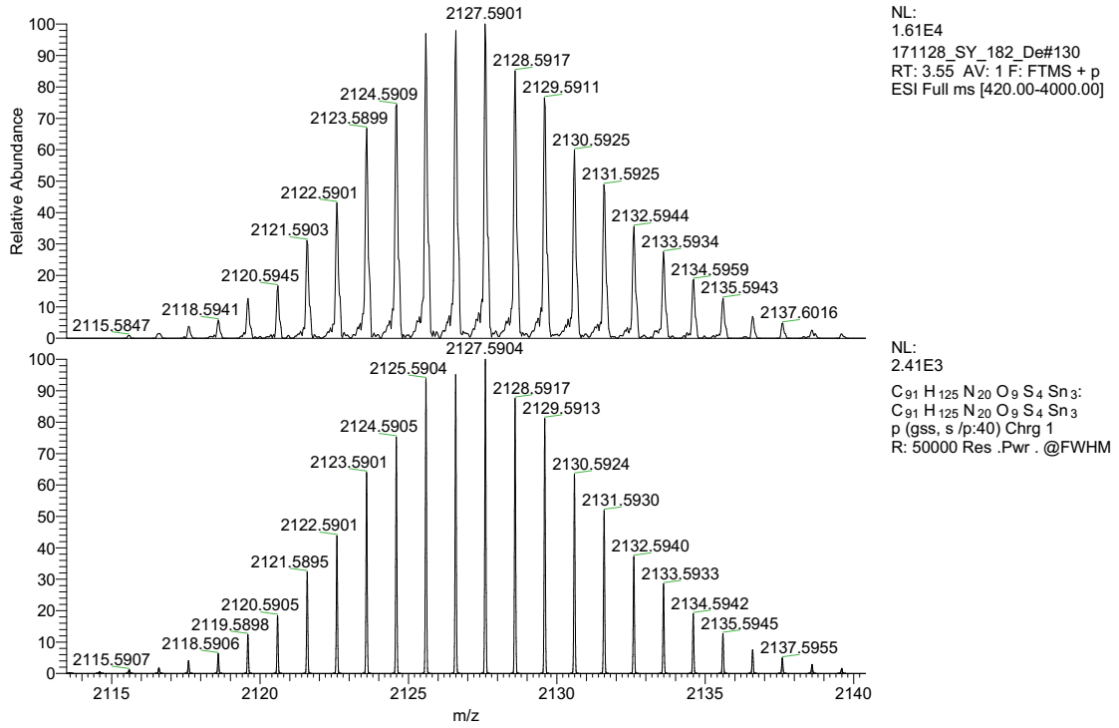


Figure S5. HRMS of the signal at 2127.5901 m/z corresponding to the sum formula $[C_{91}H_{125}N_{20}O_9S_4Sn_3]^+$.

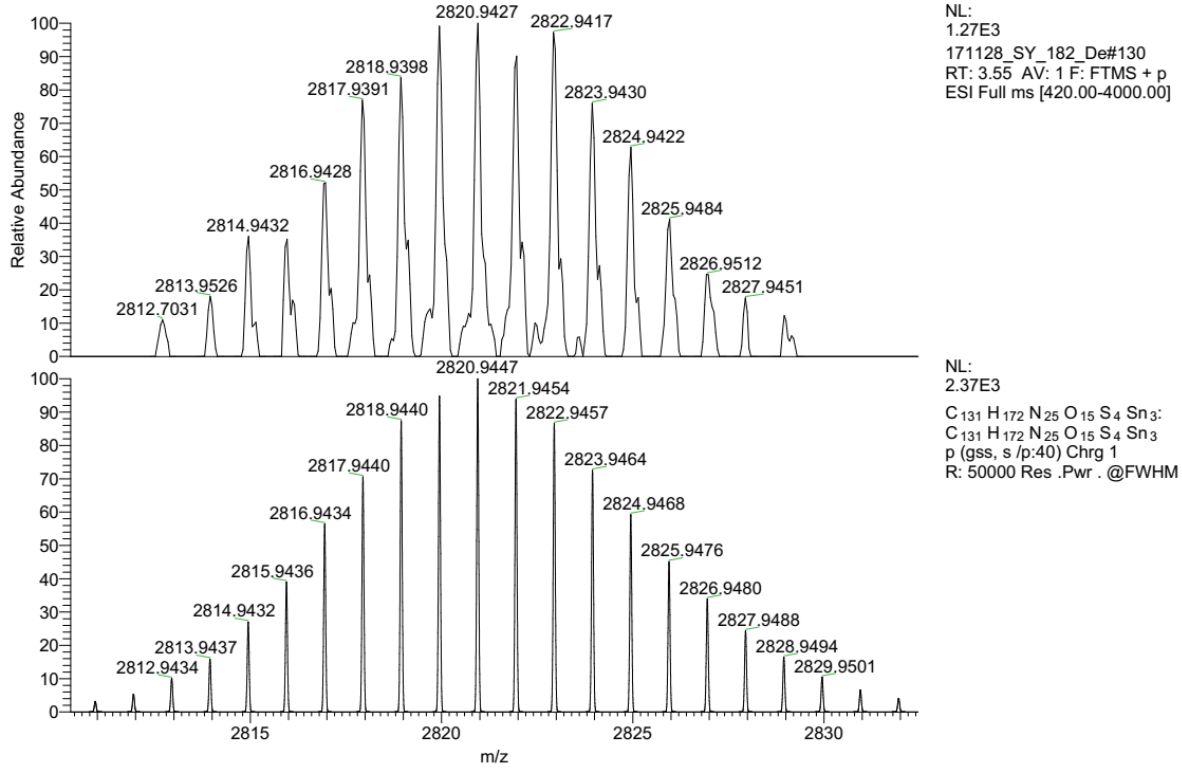


Figure S6. HRMS of the signal at 2820.9427 m/z corresponding to the sum formula $[C_{131}H_{172}N_{25}O_{15}S_4Sn_3]^+$.

IV. Quantum Chemical Investigations

Density functional calculations were carried out with TURBOMOLE[1] using def2-TZVP basis sets[2] and the BP86 functional,[3] taking advantage of the resolution-of-the-identity method.[4] Starting geometries were obtained manually using the Z-matrix editor in the program MOLDEN,[5] starting from the known crystal structure of compound **D**.[6]

V. References

[1] TURBOMOLE Version 7.3, TURBOMOLE GmbH 2018. TURBOMOLE is a development of University of Karlsruhe and Forschungszentrum Karlsruhe 1989–2007, TURBOMOLE GmbH since 2007.

[2] F. Weigend and R. Ahlrichs, *Phys. Chem. Chem. Phys.*, 2005, **7**, 3297.

[3] a) A. Becke, *Phys. Rev. A.* 1988, **38**, 3098; b) J. Perdew, *Phys. Rev. B*, 1986, **33(12)**, 8822.

[4] a) K. Eichkorn, O. Treutler, H. Öhm, M. Häser and R. Ahlrichs, *Chem. Phys. Lett.*, 1995, **240**, 283; b) K. Eichkorn, F. Weigend, O. Treutler and R. Ahlrichs, *Theor. Chem. Acc.*, 1997, **97**, 119.

[5] G. Schaftenaar and J. H. Noordik, *J. Comput. Aided. Mol. Des.*, 2000, **14**, 123.

[6] J.-P. Berndt, A. Engel, R. Hrdina, S. Dehnen and P. R. Schreiner, *Organometallics*, 2019, **38**, 329.