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John Wiley and Sons Inc.
2018-01-26

Baer, R M, Kirschner, S, Nieger, M & Bräse, S 2018, 'Alkyl and Aryl Thiol Addition to [1.1.1]Propellane : Scope and Limitations of a Fast Conjugation Reaction', Chemistry: A European Journal, vol. 24, no. 6, pp. 1373-1382. https://doi.org/10.1002/chem.201704105

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10.1002/chem.201704105

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Alkyl and aryl thiol addition to [1.1.1]propellane – scope and limitations of a fast conjugation reaction

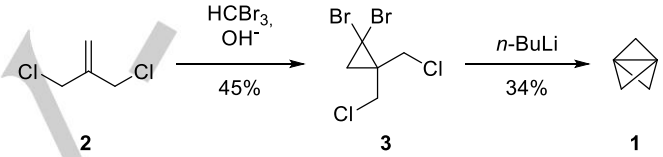
Robin M. Bär,[a] Stefan Kirschner,[a] Martin Nieger,[b] Stefan Bräse*,[a],[c]

Abstract: Herein we report the addition of different thiols to the strained carbon-carbon bond of [1.1.1]propellane (**1**). We investigated the reaction pathway, performed the addition with substituted thiols, hydrogen sulfide and protected cysteine and verified further modifications of the products. The clean reaction proceeds probably through a radical chain process as we confirmed with different deuterium labelling experiments. It shows great functional group tolerance as halogen-, hydroxy-, methoxy-, carboxy-, amino- and nitro-substituted thiols could be added to **1** with few by-products in 16–90% yield. Oxidation of the products offers a tuning of the polarity and subsequent reactions of the products. The "click"-type reaction proceeds even faster with selenols as we show in a proof-of-concept. The thiol addition to **1** offers a facile tool for surface modifications, conjugations and tuning of hydrophilicity in bio- and medicinal chemistry compounds.

Introduction

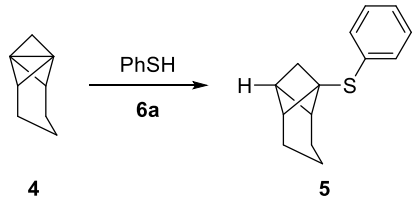
The unique structure and properties of propellanes have fascinated chemists for the last 50 years.[1] The strained molecules were named by Ginsburg *et al*. for their propeller-like shape.[2] The smallest member of this group, [1.1.1]propellane (**1**), was the first polyatomic molecule with predictions of stability, vibrational spectrum and other properties prior to its synthesis.[3] Wiberg *et al*. proved these predictions,[3b, 4] and enabled the study of this compound's reactivity.[5] An improved synthesis by Szeimies *et al*. facilitated the access to **1**, whereas the precursor **3** is readily available nowadays (Scheme 1).[6]

The compounds and subsequent polymers derived from **1** ([*n*]staffanes) gained interest in material applications, e.g. molecular construction sets,[7] liquid crystals[8] and rigid spacers.[9] More recently, the bicyclo[1.1.1]pentyl-group found use in medicinal chemistry as bioisoster of *para*-substituted benzene[10] and alkyne moieties.[11] With similar length and angle proportions, the rigid group can alter the physicochemical properties such as solubility and permeability and increase the three-dimensionality. Driven by the exploration of novel chemical space for drug development, Bunker *et al*. developed a facile route to bicyclo[1.1.1]pentylamine, a useful building block, in four steps from **1**.[12] The group of Baran reported a method for direct "propellerization" of amines by strain-release amination.[13] This click-like reaction[14] enables the late-stage modification of amines *via* the turbo-amides.



Scheme 1. Synthesis of [1.1.1]propellane (**1**) by Szeimies *et al*.[6]

The reaction of [1.1.1]propellanes like **4** with thiophenol (**6a**) occurs rapidly, as Szeimies *et al*. were the first to mention in 1985 (Scheme 2).[6] The reaction of **1** with **6a** became a method for quantification of **1** in solution, given the high yield.[5, 15] However, no systematic investigation of the thiol addition to **1** has been published so far.[5-7, 15-16] For example, only thiophenyl itself was used as thiol moiety. The addition of thiols to similar systems, e.g. housanes, has already illustrated the importance of such modifications.[17]



Scheme 2. First addition of thiophenol (**6a**) to a [1.1.1]propellane (**4**).[6]

In this study we added different thiols to **1** in order to obtain bicyclo[1.1.1]pentylsulfides in simple reactions. These reactions occurred at room temperature in short time without any catalysts and showed good functional group tolerance. Further modification of the thioethers enable a variety of applications, e.g. in surface or peptide modifications or as novel building blocks in medicinal chemistry.

Results and Discussion

The preparation of **1** was performed from cyclopropane **3** with methyllithium in pentane/diethyl ether according to the optimized

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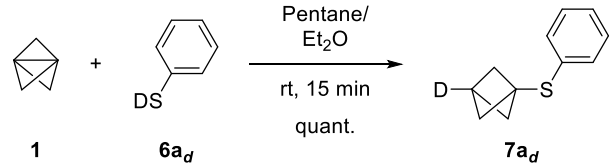
procedure by Mondanaro and Dailey.[15] By vacuum distillation of the volatiles into a cooling trap, a salt-free solution of **1** and methyl bromide was obtained. In some reactions the methyl bromide led to by-products. In this cases the procedure by Baran *et al*. was used to synthesize a pure stock solution of **1** with phenyllithium.[13] As mentioned previously, the reaction of **1** with thiophenol (**6a**) occurs quantitatively and was used to quantify the amount of **1** in the solution. With this procedures yields of 49–73% (based on **3**) were obtained.

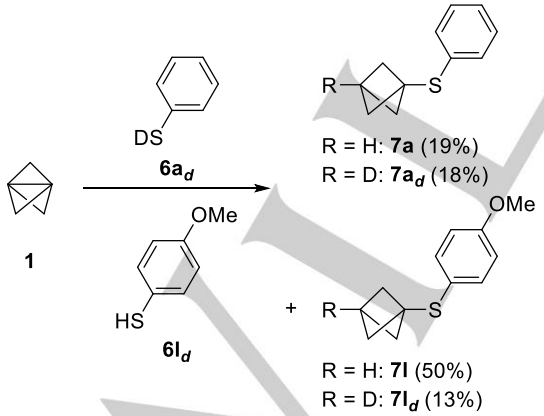
The highly strained central bond of **1** is known to react with free radicals.[5] The resulting bicyclo[1.1.1]pentyl radical is very stable compared to the corresponding cation. This is the reason for very few by-products in this kind of reaction.[18] It is already known that **1** inserts into disulfide bonds.[5] The very fast addition of thiophenoxy radicals to **1** suggest a similar mechanism for the thiol addition.[19]



1 **6a$_d$** **7a$_d$**

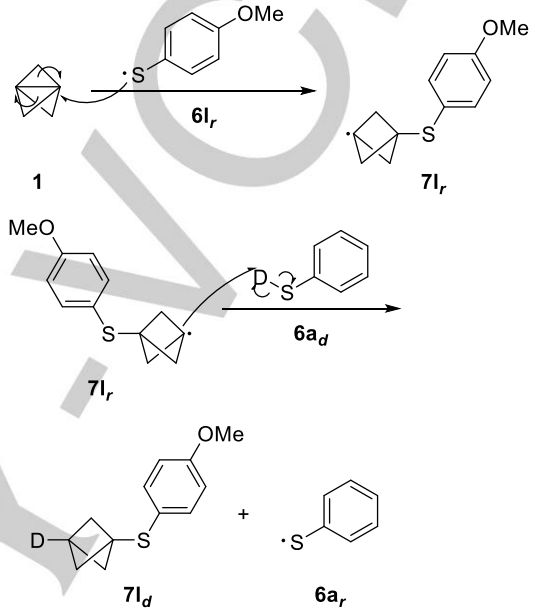
Scheme 3. Addition of deuterated thiophenol (**6a$_d$**) to **1**. The central C–C bond opens to form the bicyclo[1.1.1]pentane **7a$_d$**.

As a first step towards the elucidation of the mechanism of the thiol addition to **1**, we performed the reaction with deuterated thiophenol (**6a$_d$**) (Scheme 3). The ^{1}H NMR spectrum of the product **7a$_d$** showed a decreased signal for the bridgehead proton by 85% (ESI S5). With regards to the 85% deuterated thiol **6a$_d$** (ESI S4), this indicates the expected opening of the central CC bond. The signals of the CH_2 groups show a slight upfield shift for the deuterated compound **7a$_d$**. In the ^{13}C NMR spectrum both the signals for the bridgehead carbon and the quaternary carbon of the bicyclo[1.1.1]pentane disappear almost completely (ESI S6). The strong through space orbital communication between these two atoms have been known for a long time.[16b, 20]



Scheme 4. Competitive reaction of deuterated thiophenol (**6a$_d$**) and 4-methoxythiophenol (**6l**) with **1**. The reaction was performed in Et_2O for 15 min at room temperature.

Szeimies *et al*. already proposed a radical chain mechanism for this reaction.[6] This would request a bicyclo[1.1.1]pentyl radical **7$_r$** that could be trapped by another thiol proton. To get a deeper insight into the reaction pathway we performed a competitive reaction of **1** with **6a$_d$** and the *para*-methoxy derivative of thiophenol **6l** (Scheme 4). We obtained a mixture of four deuterated and non-deuterated products (ESI S7). The existence of **7l$_d$** supports the proposal of a bicyclo[1.1.1]pentyl radical **7$_r$** as it cannot be formed by an insertion of **1** into **6l** (Scheme 5). To exclude a proton-deuterium exchange of the products **7a$_d$** and **7l** we stirred these compounds together in diethyl ether for two days. No deuterated **7l$_d$** could be observed in this mixture (ESI S8).



Scheme 5. Proposed reaction pathway for the formation of **7l$_d$**.

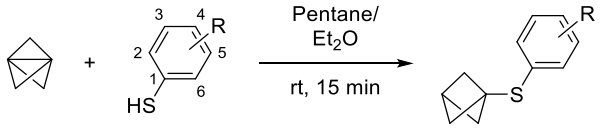
To investigate the scope and the tolerated functional groups in this reaction, different thiols were added to **1**. Therefore, a stock solution of the according thiol was added in a slight excess to the propellane solution. After 15 min of stirring at room temperature, the reaction was finished. Contrary to the reported addition of **6a** to **1** where the reaction mixture was irradiated with visible light, the reaction also proceeds in the dark.[5] The remaining thiol was removed by washing with NaOH-solution and the solvent was removed *in vacuo*. If necessary, the product was purified *via* column chromatography, but in most cases the product was obtained purely. The results of the thiol addition are divided into aromatic thiols (Table 1), aliphatic thiols (Table 2) and dithiols (Table 3).

Monohalogenated aromatic thiols led to the desired product in moderate to very good yields (Table 1, Entries 2–5), whereas dihalogenated thiols only showed fair yields (Entries 6–7). However, it is noteworthy that halides are tolerated in this reaction and no by-products were detected at all. Alkyl-substituted aromatic thiols reacted very well with **1**, except for **6h** which only led to 57% yield (Entries 8–11). No by-products were obtained for neither the alkyl-substituted nor the 2-hydroxy-substituted product **7m**. The latter gave a yield of 61% (Entry 13).

In the case of activated aromatic thiols like **6l** (Entry 12), a nucleophilic substitution of methyl bromide in the stock solution of **1** took place. This led to the methylation of the thiols and therefore decreased the yield of the desired products. To verify this

observation, a solution of **1** and methyl bromide was treated with an excess of **6a** first to remove the propellane. After 15 min, **6l** was added and the solution was stirred for further 15 min. After washing of the organic solution and removing the solvent, the two expected products **7a** and methylated **6l** were obtained.

To overcome this issue in the thiol addition, two equivalents of the thiols were used and the products could be separated in most cases by column chromatography. To avoid the formation of the by-product in order to simplify the purification, **1** was prepared with phenyllithium according to Baran *et al*.[13] With no methyl bromide in the stock solution, the sulfides were obtained purely after one washing step.



1 **6** **7**

Table 1. Results of the addition of aromatic thiols **6** to **1**.

Entry	Thiol	R	Stock solution of thiol	Product	Yield[a] [%]
1	**6a**	H	1 M in Et_2O	**7a**	quant.[b]
2	**6b**	2-Cl	1 M in Et_2O	**7b**	58
3	**6c**	3-Cl	1 M in Et_2O	**7c**	72
4	**6d**	4-Cl	1 M in Et_2O	**7d**	87
5	**6e**	4-Br	1 M in Et_2O	**7e**	65
6	**6f**	2,6-Cl_2	1 M in Et_2O / neat	**7f**	65
7	**6g**	3,5-Cl_2	1 M in Et_2O	**7g**	60
8	**6h**	2-Me	1 M in Et_2O	**7h**	57
9	**6i**	4-Me	1 M in Et_2O	**7i**	87
10	**6j**	2,4,6-Me_3	1 M in Et_2O	**7j**	84
11	**6k**	4-*t*Bu	1 M in Et_2O	**7k**	79
12	**6l**	4-OMe	1 M in Et_2O	**7l**	90
13	**6m**	2-OH	1 M in Et_2O	**7m**	61
14	**6n**	3-NH_2	1 M in Et_2O	**7n**	64
15	**6o**	4-NH_2	1 M in Et_2O	**7o**	16
16	**6p**	4-NO_2	0.5 M in THF	**7p**	47
17	**6q**	2-COOH	neat	**7q**	30[c]
18	**6r**	3-COOH	neat	**7r**	53[c]

[a] Isolated yield. [b] Based on literature.[5] [c] 1 h reaction time.

Amino, nitro and carboxyl groups were also tolerated in the reaction (Entries 14–18). However, the yields decreased significantly with these thiols. *Para*- and *ortho*-substituted aromatic thiols led to the lowest yields. As no large amounts of by-products could be detected, we suppose that these products are unstable. When stored at room temperature the amines **7n** and **7o** decomposed after few days.

The carboxylic acids **6q** and **6r** did not dissolve in the nonpolar solvents used in this reaction. To our surprise, the neat acids without any solvent reacted with **1** in the usual stock solution to achieve the desired product. The reaction time increased to 1 h for the neat thiols. We suppose that to some extent, the acids dissolve in diethyl ether and whenever the thiol reacts with **1** further acid can dissolve in solution. With this discovery, we repeated the synthesis of **7f** without dissolving the thiol prior to the addition of **1**. We obtained the product in similar yields.

For the products **7q** and **7r** we were able to grow single crystals and determine the structure *via* X-ray diffraction (Figure 1). So far, only a few crystal structures of bicyclo[1.1.1]pentylsulfides were published and none of them contained a monosulfide with a terminal bicyclopentane moiety.[16c, 21] Both carboxylic acids form dimers and the bicyclo[1.1.1]pentyl-group shows a very short distance between the two bridgehead carbons of 1.859 Å for **7q** and 1.852 Å for **7r**, respectively.

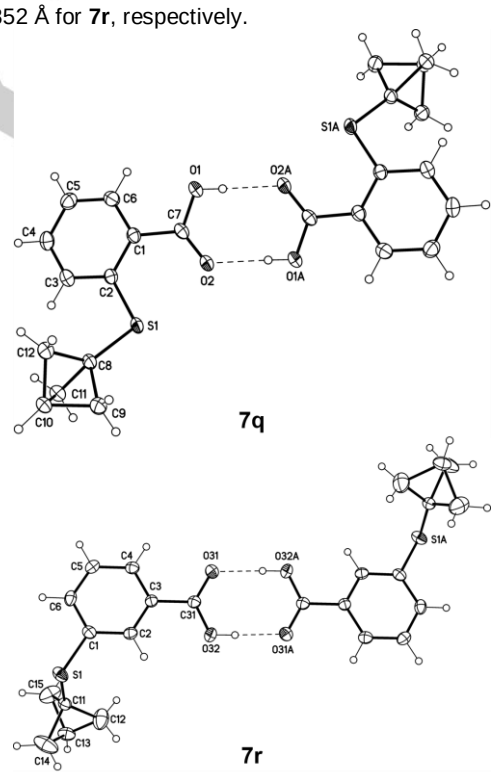
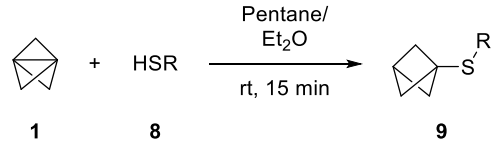


Figure 1. Structures of **7q** and **7r** dimers determined by single crystal X-ray diffraction.

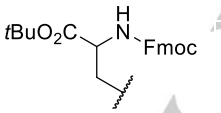
Aliphatic thiols **8** also reacted with **1** without the formation of any by-product (Table 2). Simple alkyl thiols such as **8a**–**d** reacted with **1** in poor to very good yields (Entries 1–4), whereas the branched alkyl thiols yielded lower than the corresponding linear alkyl thiols. It has to be noticed here, that these small compounds

are volatile and the isolated yields varied in repeated reactions. The addition of 2-mercaptoethanol (**8e**) and thioglycolic acid (**8f**) to **1** worked well with 77% and 66% yield, respectively, and demonstrated the tolerance of hydroxyl and carboxyl groups for alkyl thiols (Entry 5–6). Benzyl mercaptane (**8g**) reacted with **1** in 53% yield (Entry 7). Unfortunately, a debenzylation of **9g** to bicyclo[1.1.1]pentylthiol was not successful, probably due to a rearrangement to a cyclobutane similar to the known rearrangement of **1** with acids[4a] and subsequent hydrogenation. One of the most interesting thiols was the protected cysteine **8h**. The addition of this compound to **1** enables peptide modifications and leads to the new unnatural amino acid **9h** (Entry 8).



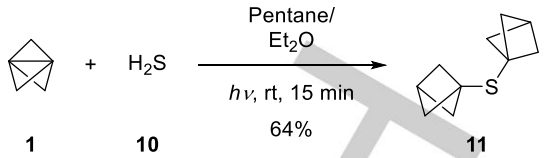
1 **8** **9**

Table 2. Results of the addition of aliphatic thiols **8** to **1**.

Entry	Thiol	R	Stock solution of thiol	Product	Yield[a] [%]
1	**8a**	*n*Pr	1 M in Et_2O	**9a**	81
2	**8b**	*i*Pr	1 M in Et_2O	**9b**	35
3	**8c**	*n*Bu	1 M in Et_2O	**9c**	67
4	**8d**	*t*Bu	1 M in Et_2O	**9d**	39
5	**8e**	$(CH_2)_2OH$	1 M in Et_2O	**9e**	77
6	**8f**	CH_2CO_2H	1 M in Et_2O	**9f**	66
7	**8g**	Bn	1 M in Et_2O	**9g**	53
8	**8h**		0.1 M in THF	**9h**	45

[a] Isolated yield.

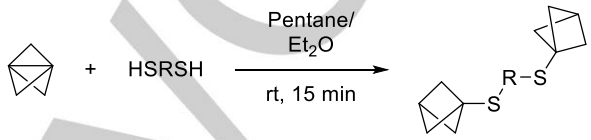
In the case of hydrogen sulfide (**10**) irradiation with UV-light (254 nm) was necessary to initiate the radical formation (Scheme **6**). In a first thiol addition, bicyclo[1.1.1]pentylthiol was formed, which reacted with a second equivalent to form the disubstituted product **11** with 64% yield.



1 **10** **11**

Scheme 6. Addition of hydrogen sulfide (**10**) (0.8 M in THF) to **1**. The reaction was initiated with UV-light (254 nm).

The same disubstitution was observed for the dithiols **12** (Table **3**). The compounds **13** were formed in satisfactory yields. Longer reaction times or more equivalents of the thiols did not increase the formation of the desired products.



1 **12** **13**

Table 3. Addition of dithiols to **1**. Two equivalents of **1** were used to obtain the disubstituted products **13**.

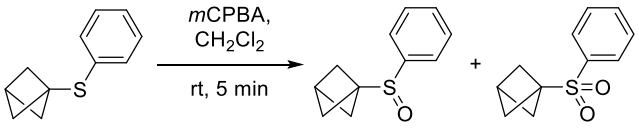
Entry	Thiol	R	Stock solution of thiol	Product	Yield[a] [%]
1	**12a**	$(CH_2)_2$	1 M in Et_2O	**13a**	31
2	**12b**	$(CH_2)_4$	1 M in Et_2O	**13b**	31
3	**12c**	$(CH_2)_6$	1 M in Et_2O	**13c**	47

[a] Isolated yield.

For potential applications it may be necessary to further modify the products of the thiol addition to **1**. To tune the polarity oxidation is the simplest way. We performed the oxidation of **7a** with different amounts of *m*CPBA to obtain the sulfoxide **14** and the sulfone **15** in a fast way and with a simple workup (Table 4). The yields were determined by analytical HPLC and show a smooth trend with the increasing amount of oxidizing agent.

The sulfoxide **14**, which is the most polar compound of this series, is obtained in the best yield with 1.5 equivalents of *m*CPBA (Entry 3). Full oxidation of all the starting material to the sulfone **15** is achieved with 3.0 equivalents of *m*CPBA (Entry 7). These products can be further modified, e.g. to sulfoximines, to enlarge the fields of applications.[22]

After the successful reactions of **1** with thiols we expanded our investigation towards selenols (Scheme 7). Due to the stronger nucleophilicity of selenols first attempts with a solution of **1** and methyl bromide led to the methylated by-product. With the pure stock solution of **1** the so far unknown selenobicyclus **17** was obtained in quantitative yield.



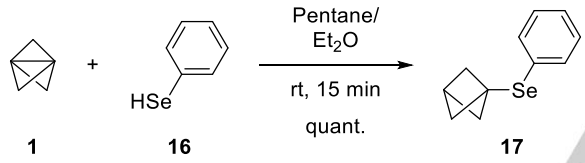
7a **14** **15**

Table 4. Oxidation of **7a** to the sulfoxide **14** and the sulfone **15**.

Entry	Equiv. of *m*CPBA	Remaining **7a**[a] [%]	Yield **14**[a] [%]	Yield **15**[a] [%]
1	1.00	52	46	2
2	1.20	47	50	3
3	1.50	15	70	15
4	1.80	12	66	22
5	2.00	–	43	57
6	2.50	–	4	96
7	3.00	–	–	quant.

[a] Determined by analytical HPLC.

In a competitive reaction of thiophenol (**6a**) and benzeneselenol (**16**) with **1** about 80% of the selenide product **17** were obtained and only 20% of the sulfide **7a** (according to NMR, ESI S9). This indicates an even more rapid reaction of seleno-compounds with **1**.



Scheme 7. The addition of benzeneselenol (**16**) to **1** afforded the product **17** in quantitative yield.

Conclusions

The thiol addition to [1.1.1]propellane is a versatile tool for many potential applications. The reaction proceeds fast, clean, without any catalyst and with no detectable amounts of by-products. Functional groups like halogens, hydroxyl, methoxy, carboxyl, amino and nitro groups are tolerated in this reaction and do not need any protection. Aromatic thiols with substituents in *ortho* or *para* position show lower yields in the addition to **1**. Especially amino and nitro groups destabilize the product. For the addition of hydrogen sulfide irradiation with UV-light was necessary to generate radicals. The synthesis of the novel amino acid **9h** enables peptide modifications that will be further studied.
Modification of the products is possible by oxidation to the corresponding sulfoxide or sulfone. The expansion of the reaction to selenols was successful and holds promise for even faster additions of such compounds. This reaction is a useful tool for modification, trapping and conjugation of thiols in many fields.

Experimental Section

For information concerning the measurements and working techniques as well as the analytical data of all other compounds, please use the supporting information. Crystallographic data can be obtained free of charge from The Cambridge Crystallographic Data Centre via www.ccdc.cam.ac.uk/data_request/cif.

*[1.1.1]Propellane (**1**):* The compound was synthesized and distilled either by **general procedure a** (with MeLi)[15] or by **general procedure b** (with PhLi) (ESI S2–S3).[13] In either case, **1** was obtained in solution and stored at –78 °C. The analytical data is in accordance with the literature.[4a]

^{1}H NMR (300 MHz, $CDCl_3$) δ = 2.00 (s, 6H, 3 x CH_2) ppm; ^{13}C NMR (75 MHz, $CDCl_3$) δ = 74.1 (–, 3 x CCH_2), 1.0 (C_{quart}, 2 x CCH_2) ppm.

The concentration of **1** was determined by using the approximately quantitative reaction of **1** with **6a** to prouct **7a**.

*1-(Phenylthio)-bicyclo[1.1.1]pentane (**7a**)*: In an argon flushed 10 mL flask a 1 M solution of thiol **6a** in Et_2O (0.68 mL, 680 µmol) was added to 1.0 mL of the stock solution of **1** (prepared by general procedure a or b) with unknown concentration. The reaction was stirred for 15 min at room temperature. The mixture was diluted with 2 mL *n*-pentane and washed with 1 M NaOH solution. The organic phase was dried over Na_2SO_4 and the solvent was removed under reduced pressure to obtain the product as a pale yellow oil. The turnover of this reaction is assumed to be quantitative to calculate the concentration of the solution of **1**. The analytical data is in accordance with the literature.[5]

^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.46–7.43 (m, 2H, Ar-H), 7.33–7.26 (m, 3H, Ar-H), 2.73 (s, 1H, C*H*), 1.96 (s, 6H, 3 × CH_2) ppm; ^{13}C NMR (100 MHz, $CDCl_3$) δ = 134.2 (C_{quart}, C_{Ar}), 133.6 (+, 2 × CH_{Ar}), 128.9 (+, 2 × CH_{Ar}), 127.6 (+, CH_{Ar}), 54.1 (–, 3 × CH_2), 45.8 (C_{quart}, $C_{Ar}SC$), 28.8 (+, *C*H) ppm; IR (ATR): $\tilde{\nu}$ = 2998 (m), 2909 (w), 2874 (w), 1583 (w), 1472 (w), 1438 (w), 1203 (m), 1128 (m), 1088 (w), 1066 (w), 1024 (w), 894 (w), 777 (vw), 741 (m), 691 (m), 548 (w), 502 (w), 423 (w), 385 (vw) cm^{-1}; MS (EI, 70 eV): *m/z* (%) = 176 (18) $[M]^+$, 135 (42) $[M–C_3H_5]^+$, 109 (71) $[M–C_5H_7]^+$, 99 (11) $[M–C_6H_5]^+$, 78 (64) $[C_6H_5+H]^+$, 77 (39) $[C_6H_5]^+$, 67 (97) $[C_5H_7]^+$, 41 (100) $[C_3H_5]^+$; HRMS (EI, 70 eV): calcd for $C_{11}H_{12}{}^{32}S$ $[M]^+$ 176.0654; found 176.0655.

General procedure c for the thiol addition to **1** as an example for **7d**:

*Bicyclo[1.1.1]pent-1-yl(4-chlorophenyl)sulfane (**7d**)*: In an argon flushed 10 mL flask a 1 M solution of thiol **6d** in Et_2O (0.390 mL, 390 µmol, 1.00 equiv.) was added to a solution of **1** (1.00 mL, 390 µmol, 1.00 equiv.) prepared by general procedure a or b. The reaction was stirred for 15 min at room temperature. The mixture was diluted with 2 mL *n*-pentane and washed with 1 M NaOH solution. The organic phase was dried over Na_2SO_4 and the solvent was removed under reduced pressure to obtain the product **7d** as a pale yellow oil in 87% yield (71.0 mg, 337 µmol).

^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.37–7.35 (m, 2H, Ar-H), 7.28–7.26 (m, 2H, Ar-H), 2.73 (s, 1H, C*H*), 1.94 (s, 6H, 3 × CH_2) ppm; ^{13}C NMR (100 MHz, $CDCl_3$) δ = 135.0 (+, 2 × CH_{Ar}), 133.8 (C_{quart}, C_{Ar}S), 132.7 (C_{quart}, C_{Ar}Cl), 129.1 (+, 2 × CH_{Ar}), 54.1 (–, 3 × CH_2), 45.7 (C_{quart}, $C_{Ar}SC$) ppm; IR (ATR): $\tilde{\nu}$ = 2979 (m), 2909 (w), 2874 (w), 1572 (w), 1473 (m), 1387 (w), 1205 (m), 1127 (m), 1092 (m), 1012 (m), 888 (w), 819 (m), 776 (w), 744 (w), 555 (w), 542 (w), 504 (m), 449 (w) cm^{-1}; MS (EI, 70 eV): *m/z* (%) = 212/210 (17/46) $[M]^+$, 169 (24) $[M–C_3H_5]^+$, 144 (65) $[M–C_5H_7+H]^+$, 134 (33) $[M–C_3H_5–Cl]^+$, 108 (37) $[M–C_5H_7–Cl]^+$, 85 (31) $[M–C_6H_4Cl–CH_3]^+$, 67 (100) $[C_5H_7]^+$; HRMS (EI, 70 eV): calcd for $C_{11}H_{11}{}^{35}Cl^{32}S$ $[M]^+$ 210.0270; found: 210.0269.

*(Bicyclo[1.1.1]pent-1-yl-3-d)(phenyl)sulfane (**7a$_d$**)*: **7a$_d$** was synthesized from a solution of **1** (general procedure a) according to the general procedure c with 85% deuterated thiophenol (**6a$_d$**) (ESI S3). The products **7a$_d$** (85%) and **7a** (15%) were obtained as a pale yellow liquid in

quantitative yield (58 mg, 327 µmol). For **7a*d*** the following analytical data was obtained.

^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.46–7.43 (m, 2H, Ar-H), 7.33–7.26 (m, 3H, Ar-H), 1.95 (s, 6H, 3 × CH_2) ppm; ^{13}C NMR (100 MHz, $CDCl_3$) δ = 134.2 (C_{quart}, C_{Ar}), 133.6 (+, 2 × CH_{Ar}), 128.9 (+, 2 × CH_{Ar}), 127.6 (+, CH_{Ar}), 54.0 (–, 3 × CH_2), 45.8 (C_{quart}, $C_{Ar}SC$) ppm; IR (ATR): $\tilde{\nu}$ = 2980 (w), 2910 (w), 2875 (w), 2227 (vw), 1583 (w), 1473 (w), 1438 (w), 1201 (m), 1120 (m), 1088 (w), 1066 (w), 1024 (w), 895 (w), 743 (m), 691 (m), 548 (w), 502 (w), 422 (vw) cm^{-1}; MS (EI, 70 eV): *m/z* (%) = 177 (45) $[M]^+$, 135 (74) $[M–C_3H_4{}^2H]^+$, 110 (100) $[M–C_5H_6{}^2H+H]^+$, 109 (27) $[M–C_5H_6{}^2H]^+$, 100 (11) $[M–C_6H_5]^+$, 77 (14) $[C_6H_5]^+$, 68 (61) $[C_5H_6{}^2H]^+$; HRMS (EI, 70 eV): calcd for $C_{11}H_{11}{}^2H^{32}S$ $[M]^+$ 177.0717; found 177.0715.

*Bicyclo[1.1.1]pent-1-yl(2-chlorophenyl)sulfane (**7b**)*: **7b** was synthesized from a solution of **1** (general procedure a) according to the general procedure c. The product **7b** was obtained as a yellow liquid in 58% yield (91.0 mg, 432 µmol).

^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.57–7.55 (m, 1H, Ar-H), 7.43–7.40 (m, 1H, Ar-H), 7.22–7.19 (m, 2H, Ar-H), 2.75 (s, 1H, C*H*), 2.02 (s, 6H, 3 × CH_2) ppm; ^{13}C NMR (100 MHz, $CDCl_3$) δ = 137.1 (C_{quart}, C_{Ar}Cl), 134.8 (+, CH_{Ar}), 133.9 (C_{quart}, C_{Ar}S), 130.0 (+, CH_{Ar}), 128.6 (+, CH_{Ar}), 127.0 (+, CH_{Ar}), 54.4 (–, 3 × CH_2), 45.4 (C_{quart}, $C_{Ar}SC$), 29.3 (+, *C*H) ppm; IR (ATR): $\tilde{\nu}$ = 2959 (w), 2913 (m), 2874 (w), 1574 (vw), 1449 (m), 1427 (w), 1375 (w), 1249 (w), 1205 (m), 1123 (w), 1035 (m), 923 (vw), 894 (w), 748 (m), 658 (w), 551 (vw), 463 (vw), 432 (w) cm^{-1}; MS (EI, 70 eV): *m/z* (%) = 212/210 (10/27) $[M]^+$, 169 (26) $[M–C_3H_5]^+$, 144 (67) $[M–C_5H_7+H]^+$, 134 (40) $[M–C_3H_5–Cl]^+$, 108 (40) $[M–C_5H_7–Cl]^+$, 85 (20) $[M–C_6H_4Cl–CH_3]^+$, 67 (100) $[C_5H_7]^+$; HRMS (EI, 70 eV): calcd for $C_{11}H_{11}{}^{35}Cl^{32}S$ $[M]^+$ 210.0270; found 210.0270.

*Bicyclo[1.1.1]pent-1-yl(3-chlorophenyl)sulfane (**7c**)*: **7c** was synthesized from a solution of **1** (general procedure b) according to the general procedure c. The product **7c** was obtained as a yellow liquid in 72% yield (53.0 mg, 252 µmol).

^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.44–7.43 (m, 1H, Ar-H), 7.32–7.30 (m, 1H, Ar-H), 7.24–7.22 (m, 2H, Ar-H), 2.75 (s, 1H, C*H*), 1.98 (s, 6H, 3 × CH_2) ppm; ^{13}C NMR (100 MHz, $CDCl_3$) δ = 136.4 (C_{quart}, C_{Ar}Cl), 134.4 (C_{quart}, C_{Ar}S), 132.9 (+, CH_{Ar}), 131.3 (+, CH_{Ar}), 129.9 (+, CH_{Ar}), 127.6 (+, CH_{Ar}), 54.2 (–, 3 × CH_2), 45.5 (C_{quart}, $C_{Ar}SC$), 29.0 (+, *C*H) ppm; IR (ATR): $\tilde{\nu}$ = 3467 (vw), 2924 (w), 2853 (w), 1746 (w), 1575 (vw), 1461 (w), 1378 (w), 1358 (w), 1247 (w), 1206 (w), 1130 (w), 1089 (m), 1069 (w), 1006 (w), 939 (vw), 891 (w), 871 (w), 853 (w), 833 (m), 814 (w), 772 (m), 681 (w), 667 (w), 545 (vw), 524 (vw) cm^{-1}; MS (EI, 70 eV): *m/z* (%) = 212/210 (15/38) $[M]^+$, 169 (23) $[M–C_3H_5]^+$, 144 (43) $[M–C_5H_7+H]^+$, 134 (37) $[M–C_3H_5–Cl]^+$, 108 (36) $[M–C_5H_7–Cl]^+$, 85 (20) $[M–C_6H_4Cl–CH_3]^+$, 67 (100) $[C_5H_7]^+$; HRMS (EI, 70 eV): calcd for $C_{11}H_{11}{}^{35}Cl^{32}S$ $[M]^+$ 210.0270; found 210.0271.

*Bicyclo[1.1.1]pent-1-yl(4-bromophenyl)sulfane (**7e**)*: **7e** was synthesized from a solution of **1** (general procedure a) according to the general procedure c. The product **7e** was obtained as a yellow liquid in 65% yield (45.0 mg, 176 µmol).

^{1}H NMR (500 MHz, $CDCl_3$): δ = 7.44–7.41 (m, 2H, Ar-H), 7.31–7.28 (m, 2H, Ar-H), 2.73 (s, 1H, C*H*), 1.95 (s, 6H, 3 × CH_2) ppm; ^{13}C NMR (125 MHz, $CDCl_3$) δ = 135.2 (+, 2 × CH_{Ar}), 133.4 (C_{quart}, C_{Ar}S), 132.0 (+, 2 × CH_{Ar}), 121.9 (C_{quart}, C_{Ar}Br), 54.1 (–, 3 × CH_2), 45.6 (C_{quart}, $C_{Ar}SC$), 28.9 (+, *C*H) ppm; IR (ATR): $\tilde{\nu}$ = 2979 (m), 2910 (w), 2875 (w), 1561 (w), 1471 (m), 1384 (w), 1205 (m), 1128 (m), 1090 (m), 1069 (m), 1009 (m), 895 (m), 815 (m), 776 (w), 729 (w), 549 (w), 511 (w), 492 (w), 445 (w) cm^{-1}; MS (EI, 70 eV): *m/z* (%) = 256/254 (26/26) $[M]^+$, 190/188 (30/29) $[M–C_5H_7+H]^+$, 134 (54) $[M–C_3H_5–Br]^+$, 109 (32) $[M–C_5H_7–Br+H]^+$, 108 (40) $[M–C_5H_7–Br]^+$, 85 (28) $[M–C_6H_4Br–CH_3]^+$, 67 (100) $[C_5H_7]^+$; HRMS (EI, 70 eV): calcd for $C_{11}H_{11}{}^{79}Br^{32}S$ $[M]^+$ 253.9759; found 253.9759.

*Bicyclo[1.1.1]pent-1-yl(2,6-dichlorophenyl)sulfane (**7f**)*: **7f** was synthesized from a solution of **1** (general procedure a) according to the general procedure c, **6f** was either added as a 1 M solution in Et_2O or as a solid. The product **7f** was obtained as a yellow solid in 65% yield (154 mg, 628 µmol).

m.p. 40–42 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ = 7.41 (d, ^3J = 7.7 Hz, 2H, Ar-H), 7.18 (dd, ^3J = 7.7 Hz, ^3J = 7.7 Hz, 1H, Ar-H), 2.67 (s, 1H, C*H*), 1.96 (s, 3 × CH_2) ppm; ^{13}C NMR (100 MHz, $CDCl_3$) δ = 142.5 (C_{quart}, 2 × C_{Ar}Cl), 131.9 (C_{quart}, C_{Ar}S), 130.2 (+, CH_{Ar}), 128.6 (+, 2 × CH_{Ar}), 54.7 (–, 3 × CH_2), 46.0 (C_{quart}, $C_{Ar}SC$), 28.5 (+, *C*H) ppm; IR (ATR): $\tilde{\nu}$ = 2980 (w), 2909 (w), 2875 (w), 1553 (m), 1422 (m), 1400 (m), 1202 (m), 1185 (m), 1123 (m), 1086 (w), 926 (w), 892 (m), 773 (s), 708 (m), 557 (w), 557 (w), 517 (w), 476 (w), 436 (w), 398 (w) cm^{-1}; MS (EI, 70 eV): *m/z* (%) = 248/246/244 (1/5/7) $[M]^+$, 209 (14) $[M–Cl]^+$, 178 (29) $[M–C_5H_7+H]^+$, 142 (28) $[M–C_5H_7–Cl]^+$, 107 (10) $[M–C_5H_7–Cl_2]^+$, 85 (22) $[M–C_6H_3Cl_2–CH_2]^+$, 67 (100) $[M–C_6H_3Cl_2S]^+$; HRMS (EI, 70 eV): calcd for $C_{11}H_{10}{}^{35}Cl_2{}^{32}S$ $[M]^+$ 243.9875; found 243.9876.

*Bicyclo[1.1.1]pent-1-yl(3,5-dichlorophenyl)sulfane (**7g**)*: **7g** was synthesized from a solution of **1** (general procedure a) according to the general procedure c. The product **7g** was obtained as a yellow liquid in 60% yield (39.0 mg, 159 µmol).

^{1}H NMR (400 MHz, $CDCl_3$) δ = 7.30 (d, ^3J = 1.8 Hz, 2H, Ar-H), 7.25 (t, ^3J = 1.8 Hz, 1H, Ar-H), 2.78 (s, 1H, C*H*), 2.02 (s, 6H, 3 × CH_2) ppm; ^{13}C NMR (100 MHz, $CDCl_3$) δ = 138.1 (C_{quart}, C_{Ar}S), 134.9 (C_{quart}, 2 × C_{Ar}Cl), 130.7 (+, 2 × CH_{Ar}), 127.5 (+, CH_{Ar}), 54.4 (–, 3 × CH_2), 45.2 (C_{quart}, $C_{Ar}SC$), 29.3 (+, *C*H) ppm; IR (ATR): $\tilde{\nu}$ = 2981 (m), 2908 (w), 2876 (w), 1554 (s), 1401 (m), 1379 (w), 1206 (m), 1141 (m), 1125 (m), 1100 (m), 894 (w), 854 (m), 795 (s), 670 (m), 428 (w) cm^{-1}; MS (EI, 70 eV): *m/z* (%) = 248/246/244 (2/10/15) $[M]^+$, 178 (20) $[M–C_5H_7+H]^+$, 142 (47) $[M–C_5H_7–Cl]^+$, 107 (12) $[M–C_5H_7–Cl_2]^+$, 99 (36) $[C_5H_7S]^+$, 85 (14) $[M–C_6H_3Cl_2–CH_3]^+$, 67 (100) $[M–C_6H_3Cl_2S]^+$; HRMS (EI, 70 eV): calcd for $C_{11}H_{10}{}^{35}Cl_2{}^{32}S$ $[M]^+$ 243.9875; found 243.9874.

*Bicyclo[1.1.1]pent-1-yl(o-tolyl)sulfane (**7h**)*: **7h** was synthesized from a solution of **1** (general procedure a) according to the general procedure c. The product **7h** was obtained as a pale yellow liquid in 57% yield (28.0 mg, 147 µmol).

^{1}H NMR (400 MHz, $CDCl_3$) δ = 7.48–7.46 (m, 1H, Ar-H), 7.24–7.12 (m, 3H, Ar-H), 2.70 (s, 1H, C*H*), 2.43 (s, 3H, CH_3), 1.94 (s, 6H, 3 × CH_2) ppm; ^{13}C NMR (100 MHz, $CDCl_3$) δ = 141.0 (C_{quart}, $C_{Ar}CH_3$), 135.0 (+, CH_{Ar}), 133.5 (C_{quart}, C_{Ar}S), 130.4 (+, CH_{Ar}), 127.9 (+, CH_{Ar}), 126.3 (+, CH_{Ar}), 54.2 (–, 3 × CH_2), 45.8 (C_{quart}, $C_{Ar}SC$), 29.0 (+, *C*H), 21.3 (+, CH_3) ppm; IR (ATR): $\tilde{\nu}$ = 2977 (m), 2909 (w), 2875 (w), 1589 (vw), 1469 (w), 1378 (w), 1203 (m), 1127 (m), 1061 (w), 1035 (w), 923 (vw), 896 (m), 779 (vw), 746 (s), 712 (m), 678 (w), 556 (vw), 460 (w), 424 (w) cm^{-1}; MS (EI, 70 eV): *m/z* (%) = 190 (10) $[M]^+$, 149 (100) $[M–C_3H_5]^+$, 124 (17) $[M–C_5H_7+H]^+$, 91 (30) $[M–C_5H_7S]^+$, 67 (18) $[C_5H_7]^+$; HRMS (EI, 70 eV): calcd for $C_{12}H_{14}{}^{32}S$ $[M]^+$ 190.0811; found 190.0809.

*Bicyclo[1.1.1]pent-1-yl(p-tolyl)sulfane (**7i**)*: **7i** was synthesized from a solution of **1** (general procedure a) according to the general procedure c. The product **7i** was obtained as a yellow liquid in 87% yield (45.0 mg, 236 µmol).

^{1}H NMR (500 MHz, $CDCl_3$): δ = 7.34–7.32 (m, 2H, Ar-H), 7.12–7.10 (m, 2H, Ar-H), 2.71 (s, 1H, C*H*), 2.34 (s, 3H, CH_3), 1.92 (s, 6H, 3 × CH_2) ppm; ^{13}C NMR (125 MHz, $CDCl_3$): δ = 137.7 (C_{quart}, $C_{Ar}CH_3$), 134.0 (+, 2 × CH_{Ar}), 130.4 (C_{quart}, $C_{Ar}S$), 129.7 (+, 2 × CH_{Ar}), 54.0 (–, 3 × CH_2), 45.9 (C_{quart}, $C_{Ar}SC$), 28.7 (+, *C*H), 21.3 (+, CH_3) ppm; IR (ATR): $\tilde{\nu}$ = 2978 (m), 2910 (w), 2874 (w), 1490 (m), 1447 (w), 1398 (vw), 1205 (m), 1129 (m), 1093 (w), 1018 (w), 890 (w), 808 (m), 775 (w), 733 (w), 706 (w), 549 (w), 507 (m), 449 (w) cm^{-1}; MS (EI, 70 eV): *m/z* (%) = 191 (13) $[M+1]^+$, 190 (87) $[M]^+$, 175 (10) $[M–CH_3]^+$, 149 (100) $[M–C_3H_5]^+$, 134 (32) $[M–C_3H_5–CH_3]^+$, 124 (85) $[M–C_5H_7+H]^+$, 123 (30) $[M–C_5H_7]^+$, 91 (87) $[M–C_5H_7S]^+$, 85 (37) $[M–C_6H_4CH_3–CH_3]^+$, 67 (52) $[C_5H_7]^+$; HRMS (EI, 70 eV): calcd for $C_{12}H_{14}{}^{32}S$ $[M]^+$ 190.0811; found 190.0812.

*Bicyclo[1.1.1]pent-1-yl(mesityl)sulfane (**7j**)*: **7j** was synthesized from a solution of **1** (general procedure a) according to the general procedure c. The product **7j** was obtained as a pale yellow liquid in 84% yield (50.0 mg, 229 µmol).

^{1}H NMR (400 MHz, $CDCl_3$): δ = 6.95–6.92 (m, 2H, Ar-H), 2.62 (s, 1H, C*H*), 2.46 (s, 6H, C^2CH_3 + C^6CH_3), 2.27 (s, 3H, C^4CH_3), 1.86 (s, 6H, 3 × CH_2) ppm; ^{13}C NMR (100 MHz, $CDCl_3$): δ = 143.6 ($C_{quart.}$, C^2 + C^6), 138.1 ($C_{quart.}$, C^4), 128.9 (+, 2 × CH_{Ar}), 128.6 ($C_{quart.}$, C^1), 54.2 (–, 3 × CH_2), 46.4 ($C_{quart.}$, C^1SC), 28.3 (+, *C*H), 22.4 (+, C^2CH_3 + C^6CH_3), 21.2 (+, C^4CH_3) ppm; IR (ATR): $\tilde{\nu}$ = 2974 (m), 2908 (w), 2872 (w), 1601 (w), 1448 (w), 1373 (w), 1203 (m), 1128 (m), 1060 (w), 1030 (w), 894 (w), 848 (m), 718 (w), 562 (w), 412 (vw) cm^{-1}; MS (EI, 70 eV): *m/z* (%) = 218 (5) $[M]^+$, 203 (11) $[M–CH_3]^+$, 177 (100) $[M–C_3H_5]^+$, 162 (35) $[M–C_3H_5–CH_3]^+$, 119 (21) $[M–C_5H_7S]^+$; HRMS (EI, 70 eV): calcd for $C_{14}H_{18}{}^{32}S$ $[M]^+$ 218.1124; found 218.1123.

*Bicyclo[1.1.1]pent-1-yl(4-(tert-butyl)phenyl)sulfane (**7k**)*: **7k** was synthesized from a solution of **1** (general procedure a) according to the general procedure c. The product **7k** was obtained as a pale yellow liquid in 79% yield (50.0 mg, 215 µmol).

^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.38–7.35 (m, 2H, Ar-H), 7.33–7.30 (m, 2H, Ar-H), 2.71 (s, 1H, C*H*), 1.95 (s, 6H, 3 × CH_2), 1.31 (s, 9H, 3 × CH_3) ppm; ^{13}C NMR (100 MHz, $CDCl_3$): δ = 150.7 ($C_{quart.}$, $C_{Ar}CCH_3$), 133.4 (+, 2 × CH_{Ar}), 130.6 ($C_{quart.}$, $C_{Ar}S$), 125.9 (+, 2 × CH_{Ar}), 54.1 (–, 3 × CH_2), 45.8 ($C_{quart.}$, $C_{Ar}SC$), 34.7 ($C_{quart.}$, CCH_3), 31.4 (+, 3 × CH_3), 28.8 (+, *C*H) ppm; IR (ATR): $\tilde{\nu}$ = 2961 (m), 2907 (w), 2873 (w), 1488 (w), 1460 (w), 1393 (w), 1362 (w), 1266 (w), 1203 (m), 1129 (w), 1116 (m), 1013 (w), 895 (w), 827 (m), 742 (w), 561 (m), 410 (vw) cm^{-1}; MS (EI, 70 eV): *m/z* (%) = 232 (42) $[M]^+$, 217 (100) $[M–CH_3]^+$, 151 (25) $[M–CH_3–C_5H_7]^+$, 85 (23) $[M–C_6H_4C(CH_3)_3–CH_2]^+$, 67 (11) $[C_5H_7]^+$, 57 (27) $[C(CH_3)_3]^+$; HRMS (EI, 70 eV): calcd for $C_{15}H_{20}{}^{32}S$ $[M]^+$ 232.1280; found 232.1279.

*Bicyclo[1.1.1]pent-1-yl(4-methoxyphenyl)sulfane (**7l**)*: **7l** was synthesized from a solution of **1** (general procedure b) according to the general procedure c. The product **7l** was obtained as a pale yellow liquid in 90% yield (111 mg, 538 µmol).

^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.40–7.35 (m, 2H, Ar-H), 6.86–6.82 (m, 2H, Ar-H), 3.81 (s, 3H, CH_3), 2.69 (s, 1H, C*H*), 1.88 (s, 6H, 3 × CH_2) ppm; ^{13}C NMR (100 MHz, $CDCl_3$) δ = 159.7 (C_{quart}, $C_{Ar}OCH_3$), 136.0 (+, 2 × CH_{Ar}), 124.5 (C_{quart}, $C_{Ar}S$), 114.5 (+, 2 × CH_{Ar}), 55.4 (+, CH_3), 53.8 (–, 3 × CH_2), 46.3 (C_{quart}, $C_{Ar}SC$), 28.5 (+, *C*H) ppm; IR (ATR): $\tilde{\nu}$ = 2977 (m), 2908 (w), 2874 (w), 2835 (w), 1590 (m), 1571 (w), 1491 (s), 1462 (m), 1440 (w), 1284 (m), 1242 (s), 1205 (m), 1171 (m), 1130 (m), 1096 (m), 1030 (m), 892 (m), 826 (m), 798 (m), 640 (w), 628 (w), 550 (w), 525 (w), 457 (vw) cm^{-1}; MS (EI, 70 eV): *m/z* (%) = 206 (100) $[M]^+$, 165 (23) $[M–C_3H_5]^+$, 140 (66) $[M–C_5H_7+H]^+$, 139 (35) $[M–C_5H_7]^+$, 125 (33) $[M–C_5H_7–CH_3+H]^+$, 124 (9) $[M–C_5H_7–CH_3+H]^+$, 121 (45) $[M–C_4H_7–OCH_3]^+$, 85 (20) $[M–C_6H_4OCH_3–CH_3]^+$, 67 (18) $[C_5H_7]^+$; HRMS (EI, 70 eV): calcd for $C_{12}H_{14}O^{32}S$ $[M]^+$ 206.0765; found 206.0764.

*2-(Bicyclo[1.1.1]pent-1-ylthio)phenol (**7m**)*: **7m** was synthesized from a solution of **1** (general procedure a) according to the general procedure c. The product **7m** was obtained as a pale yellow liquid in 61% yield (91.0 mg, 473 µmol).

^{1}H NMR (500 MHz, $CDCl_3$): δ = 7.40 (dd, ^3J = 7.5 Hz, ^4J = 1.6 Hz, 1H, Ar-H), 7.28 (ddd, ^3J = 8.2 Hz, ^3J = 6.3 Hz, ^4J = 1.6 Hz, 1H, Ar-H), 7.00 (dd, ^3J = 8.2 Hz, ^4J = 1.3 Hz, 1H, Ar-H), 6.87 (ddd, ^3J = 7.5 Hz, ^3J = 6.3 Hz, ^4J = 1.3 Hz, 1H, Ar-H), 6.70 (s, 1H, O*H*), 2.69 (s, 1H, C*H*), 1.87 (s, 6H, 3 × CH_2) ppm; ^{13}C NMR (125 MHz, $CDCl_3$): δ = 157.1 ($C_{quart.}$, $C_{Ar}OH$), 136.7 (+, CH_{Ar}), 131.4 (+, CH_{Ar}), 120.7 (+, CH_{Ar}), 117.4 ($C_{quart.}$, $C_{Ar}S$), 114.8 (+, CH_{Ar}), 53.9 (–, 3 × CH_2), 45.4 ($C_{quart.}$, $C_{Ar}SC$), 28.3 (+, *C*H) ppm; IR (ATR): $\tilde{\nu}$ = 3403 (w), 2979 (m), 2909 (w), 2875 (w), 1573 (w), 1469 (s), 1342 (w), 1287 (w), 1240 (m), 1202 (s), 1128 (m), 1026 (m), 888 (m), 830 (w), 751 (s), 680 (w), 527 (w), 475 (m), 429 (w), 395 (w) cm^{-1}; MS (EI, 70 eV): *m/z* (%) = 192 (5) $[M]^+$, 151 (100) $[M–C_3H_5]^+$, 126 (16) $[M–C_5H_7+H]^+$, 125 (3) $[M–C_5H_7]^+$, 67 (16) $[C_5H_7]^+$; HRMS (EI, 70 eV): calcd for $C_{11}H_{12}O^{32}S$ $[M]^+$ 192.0603; found 192.0605.

*3-(Bicyclo[1.1.1]pent-1-ylthiol)aniline (**7n**)*: **7n** was synthesized from a solution of **1** (general procedure a) according to the general procedure c. The product **7n** was obtained as a pale yellow liquid in 64% yield (47.0 mg, 246 µmol).

^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.10–7.05 (m, 1H, Ar-H), 6.86–6.81 (m, 1H, Ar-H), 6.78–6.76 (m, 1H, Ar-H), 6.61–6.57 (m, 1H, Ar-H), 3.65 (b, 2H, NH_2), 2.72 (s, 1H, C*H*), 1.97 (s, 6H, 3 × CH_2) ppm; ^{13}C NMR (100 MHz, $CDCl_3$): δ = 146.7 ($C_{quart.}$, $C_{Ar}NH_2$), 135.0 ($C_{quart.}$, $C_{Ar}S$), 129.6 (+, CH_{Ar}), 123.6 (+, CH_{Ar}), 119.8 (+, CH_{Ar}), 114.4 (+, CH_{Ar}), 54.2 (–, 3 × CH_2), 45.6 ($C_{quart.}$, $C_{Ar}SC$), 28.8 (+, *C*H) ppm; IR (ATR): $\tilde{\nu}$ = 3351 (w), 2977 (m), 2907 (w), 2873 (w), 1616 (m), 1588 (s), 1478 (m), 1438 (w), 1297 (w), 1263 (w), 1204 (m), 1163 (w), 1127 (m), 1078 (w), 992 (w), 886 (w), 771 (m), 687 (m), 529 (w), 446 (w) cm^{-1}; MS (EI, 70 eV): *m/z* (%) = 192 (6) $[M+H]^+$, 191 (49) $[M]^+$, 150 (26) $[M–C_3H_5]^+$, 125 (100) $[M–C_5H_7+H]^+$, 124 (13) $[M–C_5H_7]^+$, 106 (34) $[M–C_5H_8–NH_2]^+$; HRMS (EI, 70 eV): calcd for $C_{11}H_{13}N^{32}S$ $[M]^+$ 191.0763; found 191.0763.

*4-(Bicyclo[1.1.1]pent-1-ylthiol)aniline (**7o**)*: **7o** was synthesized from a solution of **1** (general procedure b) according to the general procedure c. The product **7o** was obtained as a yellow oil in 16% yield (11.0 mg, 57.5 µmol).

^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.26–7.23 (m, 2H, Ar-H), 6.63–6.61 (m, 2H, Ar-H), 3.70 (b, 2H, NH_2), 2.68 (s, 1H, C*H*), 1.86 (s, 6H, 3 × CH_2) ppm; ^{13}C NMR (100 MHz, $CDCl_3$): δ = 146.5 ($C_{quart.}$, $C_{Ar}NH_2$), 136.2 (+, 2 × CH_{Ar}), 121.5 ($C_{quart.}$, $C_{Ar}S$), 115.5 (+, 2 × CH_{Ar}), 53.7 (–, 3 × CH_2), 46.4 ($C_{quart.}$, $C_{Ar}SC$), 28.4 (+, *C*H) ppm; IR (ATR): $\tilde{\nu}$ = 3431 (w), 3342 (m), 3213 (w), 3021 (vw), 2971 (m), 2905 (w), 2872 (w), 1884 (vw), 1631 (m), 1593 (m), 1491 (m), 1423 (w), 1296 (m), 1201 (m), 1177 (m), 1125 (m), 1096 (m), 1063 (w), 1006 (vw), 935 (vw), 890 (m), 814 (s), 771 (w), 646 (w), 546 (w), 517 (s), 423 (w), 406 (w) cm^{-1}; MS (EI, 70 eV): *m/z* (%) = 192 (14) $[M+H]^+$, 191 (100) $[M]^+$, 150 (22) $[M–C_3H_5]^+$, 125 (65) $[M–C_5H_7+H]^+$, 124 (62) $[M–C_5H_7]^+$, 106 (49) $[M–C_5H_8–NH_2]^+$; HRMS (EI, 70 eV): calcd for $C_{11}H_{13}N^{32}S$ $[M]^+$ 191.0763; found 191.0764.

*Bicyclo[1.1.1]pent-1-yl(4-nitrophenyl)sulfane (**7p**)*: **7p** was synthesized from a solution of **1** (general procedure b) according to the general procedure c, but **6p** was added as a 0.5 M solution in THF. The product **7p** was obtained as a yellow solid that melts around room temperature in 47% yield (62.0 mg, 280 µmol).

^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.15–8.12 (m, 2H, Ar-H), 7.53–7.49 (m, 2H, Ar-H), 2.84 (s, 1H, C*H*), 2.13 (s, 6H, 3 × CH_2) ppm; ^{13}C NMR (100 MHz, $CDCl_3$): δ = 146.2 ($C_{quart.}$, $C_{Ar}NO_2$), 145.6 ($C_{quart.}$, C_{Ar}S), 130.7 (+, 2 × CH_{Ar}), 123.9 (+, 2 × CH_{Ar}), 54.7 (–, 3 × CH_2), 44.6 ($C_{quart.}$, C_{Ar}S*C*), 30.0 (+, *C*H) ppm; IR (ATR): $\tilde{\nu}$ = 2983 (w), 2913 (w), 2877 (w), 1594 (w), 1575 (m), 1475 (w), 1336 (s), 1259 (w), 1208 (m), 1124 (m), 1090 (m), 1012 (w), 892 (w), 851 (m), 742 (m), 684 (w), 535 (w), 408 (vw) cm^{-1}; MS (EI, 70 eV): *m/z* (%) = 222 (6) $[M+1]^+$, 221 (38) $[M]^+$, 180 (7) $[M–C_3H_5]^+$, 134 (31) $[M–C_3H_5–NO_2]^+$, 85 (12) $[M–C_6H_4NO_2–CH_3]^+$, 67 (100) $[C_5H_7]^+$; HRMS (EI, 70 eV) calcd for $C_{11}H_{11}O_2N^{32}S$ $[M]^+$ 221.0505; found 221.0506.

*2-(Bicyclo[1.1.1]pent-1-ylthio)benzoic acid (**7q**)*: **7q** was synthesized from a solution of **1** (general procedure b) according to the general procedure c, but **6q** was added as a solid. Afterwards the crude product was purified by column chromatography (SiO_2, cyclohexane/EtOAc/AcOH, 5/1/0.01). The product **7q** was obtained as a white solid in 30% yield (29.0 mg, 132 µmol).

R_f (SiO_2, cyclohexane/EtOAc/AcOH, 5/1/0.01): 0.22; m.p. 125–127 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.17 (dd, ^3J = 7.8 Hz, ^4J = 1.5 Hz, 1H, Ar-H), 7.64 (dd, ^3J = 7.8 Hz, ^4J = 1.1 Hz, 1H, Ar-H), 7.50 (ddd, ^3J = 7.8 Hz, ^3J = 7.6 Hz, ^4J = 1.5 Hz, 1H, Ar-H), 7.34 (ddd, ^3J = 7.8 Hz, ^3J = 7.6 Hz, ^3J = 1.1 Hz, 1H, Ar-H), 2.81 (s, 1H, C*H*), 2.08 (s, 6H, 3 × CH_2) ppm; ^{13}C NMR (100 MHz, $CDCl_3$): δ = 169.7 ($C_{quart.}$, CO_2H), 132.9 ($C_{quart.}$, C_{Ar}S), 132.8 (+, 2 × CH_{Ar}), 132.7 (+, CH_{Ar}), 129.9 ($C_{quart.}$, $C_{Ar}CO_2$H), 127.0 (+, CH_{Ar}), 54.4 (–, 3 × CH_2), 45.3 ($C_{quart.}$, C_{Ar}S*C*), 29.8 (+, *C*H) ppm; IR (ATR): $\tilde{\nu}$ = 2971 (m), 2915 (m), 2879 (m), 2643 (w), 1673 (s), 1587 (w), 1560 (m), 1463 (m), 1434 (w), 1406 (m), 1309 (m), 1251 (s), 1206 (m), 1135 (m), 1056 (m), 1043 (m), 917 (m), 893 (m), 806 (w), 737 (s), 692 (m), 650 (m), 557 (m), 491 (w), 464 (w), 416 (w) cm^{-1}; MS (EI, 70 eV): *m/z* (%) = 221 (1) $[M+1]^+$, 220 (4) $[M]^+$, 179 (10) $[M–C_3H_5]^+$, 136 (100) $[M–C_3H_5–CO_2+H]^+$, 109 (11) $[M–C_5H_7–CO_2]^+$, 99 (64) $[M–C_6H_4CO_2H]^+$, 67 (37) $[C_5H_7]^+$; HRMS (EI, 70 eV): calcd for $C_{12}H_{12}O_2{}^{32}S$ $[M]^+$ 220.0558; found 220.0559.

For crystallographic data of this compound please use the supporting information. CCDC 1575329 contains the supplementary crystallographic data for this compound.

*3-(Bicyclo[1.1.1]pent-1-ylthio)benzoic acid (**7r**)*: **7r** was synthesized from a solution of **1** (general procedure a) according to the general procedure c, but **6r** was added as a solid. Afterwards the crude product was purified by column chromatography (SiO_2, cyclohexane/EtOAc/AcOH, 5/1/0.01). The product **7r** was obtained as a white solid in 53% yield (63.0 mg, 286 µmol).

R_f (SiO_2, cyclohexane/EtOAc/AcOH, 5/1/0.01): 0.29; m.p. 108–110 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.12 (dd, ^4J = 1.8 Hz, ^4J = 1.8 Hz, 1H, Ar-H), 7.94 (ddd, ^3J = 7.8 Hz, ^4J = 1.8 Hz, ^4J = 1.3 Hz, 1H, Ar-H), 7.60 (ddd, ^3J = 7.7 Hz, ^4J = 1.8 Hz, ^4J = 1.3 Hz, 1H, Ar-H), 7.35 (dd, ^3J = 7.8 Hz, ^3J = 7.7 Hz, 1H, Ar-H), 2.69 (s, 1H, C*H*), 1.93 (s, 6H, 3 × CH_2) ppm; ^{13}C NMR (100 MHz, $CDCl_3$): δ = 170.5 ($C_{quart.}$, CO_2H), 138.4 (+, CH_{Ar}), 135.5 ($C_{quart.}$, C_{Ar}S), 134.7 (+, CH_{Ar}), 129.9 ($C_{quart.}$, $C_{Ar}CO_2$H), 129.1 (+, CH_{Ar}), 129.0 (+, CH_{Ar}), 54.3 (–, 3 × CH_2), 45.5 ($C_{quart.}$, C_{Ar}S*C*), 29.1 (+, *C*H) ppm; IR (ATR): $\tilde{\nu}$ = 2986 (w), 2906 (w), 2873 (w), 2544 (w), 1686 (s), 1591 (w), 1570 (w), 1474 (w), 1420 (m), 1290 (m), 1260 (m), 1204 (m), 1165 (w), 1125 (m), 1071 (m), 928 (m), 905 (m), 886 (m), 848 (w), 813 (w), 746 (m), 720 (m), 677 (m), 656 (m), 548 (m), 515 (w), 414 (w) cm^{-1}; MS (EI, 70 eV): *m/z* (%) = 221 (5) $[M+1]^+$, 220 (36) $[M]^+$, 179 (15) $[M–C_3H_5]^+$, 154 (35) $[M–C_5H_7+H]^+$, 135 (28) $[M–C_3H_5–CO_2]^+$, 109 (10) $[M–C_5H_7–CO_2]^+$, 85 (20) $[M–CO_2H–C_6H_5–CH_2]^+$, 67 (100) $[C_5H_7]^+$; HRMS (EI, 70 eV): calcd for $C_{12}H_{12}O_2{}^{32}S$ $[M]^+$ 220.0558; found 220.0558.

For crystallographic data of this compound please use the supporting information. CCDC 1575330 contains the supplementary crystallographic data for this compound.

*Di(bicyclo[1.1.1]pent-1-yl)sulfane (**11**)*: In a quartz cuvette under argon atmosphere a 0.8 M solution of H_2S in THF (1.06 mL, 850 µmol, 1.00 equiv.) was added to a 0.37 M solution of **1** (general procedure a) (2.30 mL, 850 µmol, 1.00 equiv.) and irradiated for 1 h with a 4 W UV lamp (254 nm). The reaction mixture was diluted with 2 mL *n*-pentane and washed with 1 M NaOH solution. The organic phase was dried over Na_2SO_4 and the solvent was removed under reduced pressure at room temperature to obtain the product **11** as a volatile, pale yellow liquid in 64% yield (90.0 mg, 540 µmol).

^{1}H NMR (400 MHz, $CDCl_3$): δ = 2.71 (s, 2H, 2 × C*H*), 2.04 (s, 12H, 6 × CH_2) ppm; ^{13}C NMR (100 MHz, $CDCl_3$): δ = 55.2 (–, 6 × CH_2), 44.2 ($C_{quart.}$, 2 × S*C*), 30.1 (+, 2 × *C*H) ppm; IR (ATR): $\tilde{\nu}$ = 2975 (m), 2909 (m), 2874 (m), 1447 (vw), 1201 (s), 1131 (m), 894 (m), 471 (w) cm^{-1}; MS (EI, 70 eV): *m/z* (%) = 166 (9) $[M]^+$, 125 (16) $[M–C_3H_5]^+$, 99 (34) $[M–C_5H_7]^+$, 85 (54) $[M–(C_3H_5)_2+H]^+$, 67 (100) $[C_5H_7]^+$; HRMS (EI, 70 eV): calcd for $C_{10}H_{14}{}^{32}S$ $[M]^+$ 166.0811; found 166.0812.

*Bicyclo[1.1.1]pent-1-yl(propyl)sulfane (**9a**)*: **9a** was synthesized from a solution of **1** (general procedure a) according to the general procedure c. The product **9a** was obtained as a volatile, pale yellow liquid in 81% yield (42.0 mg, 295 µmol).

^{1}H NMR (400 MHz, $CDCl_3$): δ = 2.72 (s, 1H, C*H*), 2.51 (t, ^3J = 7.3 Hz, 2H, CH_2CH$_2$CH$_3$), 1.96 (s, 6H, 3 × CCH_2CH), 1.60 (td, ^3J = 7.4 Hz, ^3J = 7.3 Hz, 2H, CH$_2$CH_2CH$_3$), 0.98 (t, ^3J = 7.4 Hz, 3H, CH_3) ppm; ^{13}C NMR (100 MHz, $CDCl_3$): δ = 53.9 (–, 3 × CCH_2CH), 44.7 ($C_{quart.}$, CCH_2CH), 33.3 (–, $CH_2CH_2CH_3$), 28.8 (+, *C*H), 23.9 (–, $CH_2CH_2CH_3$), 13.7 (+, CH_3) ppm; IR (ATR): $\tilde{\nu}$ = 2961 (m), 2907 (w), 2872 (w), 1450 (w), 1376 (vw), 1291 (vw), 1205 (m), 1140 (m), 902 (w), 797 (vw) cm^{-1}. Due to the nonpolar and volatile nature of this compound no HRMS measurement was possible with EI or FAB. In the ESI (S10) we attached a GC-MS spectrum of **9a**.

*Bicyclo[1.1.1]pent-1-yl(isopropyl)sulfane (**9b**)*: **9b** was synthesized from a solution of **1** (general procedure a) according to the general procedure c. The product **9b** was obtained as a volatile, colourless liquid in 35% yield (18.0 mg, 127 µmol).

^{1}H NMR (400 MHz, $CDCl_3$): δ = 2.96 (sept, ^3J = 6.8 Hz, 1H, C*H*$(CH_3)_2$), 2.71 (s, 1H, C*H*$(CH_2)_3$), 2.00 (s, 6H, 3 × CH_2), 1.28 (d, ^3J = 6.8 Hz, 6H, 2 × CH_3) ppm; ^{13}C NMR (100 MHz, $CDCl_3$): δ = 54.6 (–, 3 × CH_2), 44.5 ($C_{quart.}$, CHS*C*), 35.8 (+, *C*H$(CH_3)_2$), 29.2 (+, *C*H$(CH_2)_3$), 24.8 (+, 2 × CH_3) ppm; IR (ATR): $\tilde{\nu}$ = 2974 (w), 2908 (w), 2873 (w), 1447 (vw), 1381 (vw), 1364 (vw), 1243 (vw), 1206 (m), 1139 (w), 1050 (w), 903 (vw), 646 (vw) cm^{-1}. Due to the nonpolar and volatile nature of this compound no HRMS measurement was possible with EI or FAB. In the ESI (S11) we attached a GC-MS spectrum of **9b**.

*Bicyclo[1.1.1]pent-1-yl(butyl)sulfane (**9c**)*: **9c** was synthesized from a solution of **1** (general procedure a) according to the general procedure c. The product **9c** was obtained as a volatile, pale yellow liquid in 67% yield (38.0 mg, 243 µmol).

^{1}H NMR (400 MHz, $CDCl_3$): δ = 2.72 (s, 1H, C*H*), 2.53 (t, ^3J = 7.4 Hz, 2H, CH_2CH$_2$CH$_2$CH$_3$), 1.96 (s, 6H, 3 × CCH_2CH), 1.61–1.52 (m, 2H, CH$_2$CH$_2$CH_2CH$_3$), 1.44–1.35 (m, 2H, CH$_2$CH_2CH$_2$CH$_3$), 0.91 (t, ^3J = 7.3 Hz, 3H, CH_3) ppm; ^{13}C NMR (100 MHz, $CDCl_3$): δ = 53.9 (–, 3 × CCH_2CH), 44.7 ($C_{quart.}$, CCH_2CH), 33.3 (–, $CH_2CH_2CH_2CH_3$), 31.0 (–, $CH_2CH_2CH_2CH_3$), 28.8 (+, *C*H), 22.2 (–, $CH_2CH_2CH_2CH_3$), 13.9 (+, CH_3)

ppm; IR (ATR): $\tilde{\nu}$ = 2959 (w), 2907 (w), 2872 (w), 1458 (vw), 1377 (vw), 1274 (vw), 1205 (m), 1141 (w), 903 (w), 745 (vw), 395 (vw) cm^{-1}. Due to the nonpolar and volatile nature of this compound no HRMS measurement was possible with EI or FAB. In the ESI (S12) we attached a GC-MS spectrum of **9c**.

*Bicyclo[1.1.1]pent-1-yl(tert-butyl)sulfane (**9d**)*: **9d** was synthesized from a solution of **1** (general procedure a) according to the general procedure c. The product **9d** was obtained as a volatile, pale yellow liquid in 39% yield (22.0 mg, 141 µmol).

^{1}H NMR (400 MHz, $CDCl_3$): δ = 2.69 (s, 1H, C*H*), 2.08 (s, 6H, 3 × CH_2), 1.36 (s, 9H, 3 × CH_3) ppm; ^{13}C NMR (100 MHz, $CDCl_3$): δ = 56.1 (–, 3 × CH_2), 44.8 ($C_{quart.}$, *C*SC(CH$_3$)$_3$), 44.1 ($C_{quart.}$, *C*(CH$_3$)$_3$), 32.0 (+, 3 × CH_3), 30.7 (+, *C*H) ppm; IR (ATR): $\tilde{\nu}$ = 2962 (w), 2910 (w), 2874 (w), 1456 (w), 1362 (w), 1260 (vw), 1208 (m), 1164 (w), 1135 (w), 903 (w), 803 (vw), 597 (vw) cm^{-1}. Due to the nonpolar and volatile nature of this compound no HRMS measurement was possible with EI or FAB. In the ESI (S13) we attached a GC-MS spectrum of **9d**.

*2-(Bicyclo[1.1.1]pent-1-ylthio)ethan-1-ol (**9e**)*: **9e** was synthesized from a solution of **1** (general procedure a) according to the general procedure c. The organic phase was not washed with NaOH solution, but concentrated and purified by column chromatography (SiO_2, cyclohexane/EtOAc, 2:1) The product **9e** was obtained as a colourless oil in 77% yield (88.0 mg, 610 µmol).

R_f (SiO_2, cyclohexane/EtOAc, 2:1): 0.44; ^{1}H NMR (400 MHz, $CDCl_3$): δ = 3.70 (td, ^3J = 6.2 Hz, ^3J = 6.1 Hz, 2H, CH_2CH_2OH), 2.75 (t, ^3J = 6.1 Hz, 2H, CH_2CH_2OH), 2.73 (s, 1H, C*H*), 2.09 (t, ^3J = 6.2 Hz, 1H, O*H*), 1.98 (s, 6H, 3 × CCH_2CH) ppm; ^{13}C NMR (100 MHz, $CDCl_3$): δ = 61.4 (–, CH_2CH_2OH), 54.1 (–, 3 × CCH_2CH), 44.2 ($C_{quart.}$, *C*S), 34.6 (–, *C*H_2CH_2OH), 28.8 (+, *C*H) ppm; IR (ATR): $\tilde{\nu}$ = 3335 (w), 2974 (m), 2907 (w), 2872 (m), 1407 (w), 1287 (vw), 1206 (m), 1137 (m), 1041 (m), 1008 (m), 929 (w), 902 (w), 763 (w), 667 (w), 440 (vw) cm^{-1}; MS (EI, 70 eV): *m/z* (%) = 145 (1) $[M+H]^+$, 143 (1) $[M–H]^+$, 100 (70) $[M–C_2H_4OH+H]^+$, 99 (37) $[M–C_2H_4OH]^+$, 85 (100) $[M–C_2H_4OH–CH_2]^+$, 77 (10) $[M–C_5H_7]^+$, 67 (64) $[C_5H_7]^+$; HRMS (EI, 70 eV): calcd for $C_7H_{12}O_1{}^{32}S_1$ $[M]^+$ 144.0603; found 144.0605.

*2-(Bicyclo[1.1.1]pent-1-ylthio)acetic acid (**9f**)*: **9f** was synthesized from a solution of **1** (general procedure a) according to the general procedure c. The organic phase was not washed with NaOH solution, but concentrated and purified by column chromatography (SiO_2, cyclohexane/EtOAc/ trifluoroacetic acid, 10:1:0.01). The product **9f** was obtained as a colourless oil in 66% yield (59.0 mg, 373 µmol).

R_f (SiO_2, cyclohexane/EtOAc/trifluoroacetic acid, 10:1:0.01): 0.20; ^{1}H NMR (400 MHz, $CDCl_3$): δ = 3.31 (s, 2H, CSCH_2), 2.75 (s, 1H, C*H*), 2.01 (s, 6H, 3 × CCH_2CH) ppm; ^{13}C NMR (100 MHz, $CDCl_3$): δ = 175.3 ($C_{quart.}$, *C*O_2H), 53.6 (–, 3 × CCH_2CH), 44.3 ($C_{quart.}$, *C*SCH_2), 33.2 (–, CSCH_2), 28.7 (+, *C*H) ppm; IR (ATR): $\tilde{\nu}$ = 2979 (m), 2910 (m), 2876 (m), 2670 (w), 1705 (s), 1419 (w), 1291 (m), 1206 (m), 1134 (m), 900 (m), 785 (w), 668 (w), 581 (w), 464 (w) cm^{-1}; MS (EI, 70 eV): *m/z* (%) = 158 (1) $[M]^+$, 157 (2) $[M–H]^+$, 99 (100) $[M–CH_2CO_2H]^+$, 67 (79) $[C_5H_7]^+$; HRMS (EI, 70 eV): calcd for $C_7H_{10}O_2{}^{32}S$ $[M]^+$ 158.0402; found 158.0403.

*Benzyl(bicyclo[1.1.1]pent-1-yl)sulfane (**9g**)*: **9g** was synthesized from a solution of **1** (general procedure a) according to the general procedure c. The product **9g** was obtained as a pale yellow oil in 53% yield (94.0 mg, 494 µmol).

^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.32–7.17 (m, 5H, Ar-H), 3.73 (s, 2H, $C_6H_5CH_2$S), 2.64 (s, 1H, C*H*), 1.68 (s, 6H, 3 × CCH_2CH) ppm; ^{13}C NMR (100 MHz, $CDCl_3$): δ = 138.9 ($C_{quart.}$, C_{Ar}), 128.9 (+, 2 × CH_{Ar}), 128.5 (+, 2 × CH_{Ar}), 127.0 (+, CH_{Ar}), 53.8 (–, 3 × CCH_2CH), 44.8 ($C_{quart.}$, S*C*), 35.9 (–, $C_{Ar}CH_2$S), 29.0 (+, *C*H) ppm; IR (ATR): $\tilde{\nu}$ = 3060 (vw), 3026 (vw), 2974 (w), 2906 (w), 2872 (w), 1600 (vw), 1493 (w), 1451 (w), 1205 (m), 1137 (w), 1068 (w), 1028 (vw), 903 (vw), 862 (vw), 760 (vw), 696 (m), 563 (vw), 472 (vw), 440 (vw) cm^{-1}; MS (EI, 70 eV): *m/z* (%) = 190 (1) $[M]^+$, 99 (4) $[M–C_6H_5CH_2]^+$, 91 (100) $[M–C_5H_7S]^+$, 67 (3) $[C_5H_7]^+$; HRMS (EI, 70 eV) $C_{12}H_{14}{}^{32}S$ $[M]^+$ 190.0811; found 190.0811.

*Fmoc-Bicyclo[1.1.1]pentyl-Cys-OtBu (**9h**)*: **9h** was synthesized from a solution of **1** (general procedure a) according to the general procedure c, but **8h** (ESI S3) was added as a 1 M solution in THF. Afterwards the crude product was purified by column chromatography (SiO_2, cyclohexane/EtOAc, 10:1). The product **9h** was obtained as a colourless oil in 45% yield (172 mg, 369 µmol).

R_f (SiO_2, cyclohexane/EtOAc, 10:1): 0.27; ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.78–7.75 (m, 2H, Ar-H), 7.62–7.60 (m, 2H, Ar-H), 7.42–7.38 (m, 2H, Ar-H), 7.34–7.29 (m, 2H, Ar-H), 5.56 (d, ^3J = 7.8 Hz, 1H, N*H*), 4.51 (dt, ^3J = 7.8 Hz, ^3J = 4.8 Hz, 1H, SCH_2CH), 4.41 (d, ^3J = 7.0 Hz, 2H, CO_2CH_2CH), 4.23 (t, ^3J = 7.0 Hz, 1H, CO_2CH_2CH), 3.02 (dd, ^2J = 13.6 Hz, ^3J = 4.8 Hz, 1H, SCH_2CH), 2.94 (dd, ^2J = 13.6 Hz, ^3J = 4.8 Hz, 1H, SCH_2CH), 2.70 (s, 1H, $SCCH_2CH$), 1.93 (s, 6H, 3 × SCCH_2CH), 1.48 (s, 9H, 3 × CH_3) ppm; ^{13}C NMR (100 MHz, $CDCl_3$): δ = 169.7 ($C_{quart.}$, CCO_2), 155.8 ($C_{quart.}$, NCO_2), 144.0 ($C_{quart.}$, C_{Ar}), 143.9 ($C_{quart.}$, C_{Ar}), 141.5 ($C_{quart.}$, 2 × C_{Ar}), 127.9 (+, 2 × CH_{Ar}), 127.2 (+, 2 × CH_{Ar}), 125.3 (+, CH_{Ar}), 125.2 (+, CH_{Ar}), 120.1 (+, 2 × CH_{Ar}), 82.9 ($C_{quart.}$, *C*CH_3), 67.2 (–, CO_2CH_2CH), 54.4 (+, SCH_2CH), 53.8 (–, 3 × SCCH_2CH), 47.3 (+, CO_2CH_2CH), 44.4 ($C_{quart.}$, S*C*CH_2CH), 33.9 (–, S*C*H_2CH), 28.6 (+, $SCCH_2CH$), 28.2 (+, 3 × CH_3) ppm; IR (ATR): $\tilde{\nu}$ = 3331 (vw), 2976 (w), 2908 (vw), 2874 (w), 1712 (m), 1503 (w), 1449 (w), 1393 (vw), 1368 (w), 1342 (w), 1207 (m), 1151 (m), 1105 (w), 1047 (w), 999 (w), 901 (vw), 844 (w), 757 (w), 738 (m), 621 (vw), 536 (w), 424 (w) cm^{-1}; MS (EI, 70 eV): *m/z* (%) = 466 (1) $[M+H]^+$, 465 (2) $[M]^+$, 408 (15) $[M–C(CH_3)_3]^+$, 365 (38) $[M–CO_2C(CH_3)_3+H]^+$, 364 (100) $[M–CO_2C(CH_3)_3]^+$, 179 (65) $[C_{14}H_{10}+H]^+$, 178 (100) $[C_{14}H_{10}]^+$; HRMS (EI, 70 eV): calcd for $C_{27}H_{31}O_4N^{32}S$ $[M]^+$ 465.1968; found 465.1970.

*1,2-Bis(bicyclo[1.1.1]pent-1-ylthio)ethane (**13a**)*: **13a** was synthesized from a solution of **1** (general procedure a) according to the general procedure c. The product **13a** was obtained as a white solid in 31% yield (82.0 mg, 362 µmol).

m.p. 65–67 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ = 2.74 (s, 2H, 2 × C*H*), 2.72 (s, 4H, 2 × SCH_2), 1.98 (s, 12H, 6 × CCH_2CH) ppm; ^{13}C NMR (100 MHz, $CDCl_3$): δ = 54.1 (–, 6 × CCH_2CH), 44.5 ($C_{quart.}$, 2 × S*C*), 32.2 (–, 2 × SCH_2), 28.8 (+, 2 × *C*H) ppm; IR (ATR): $\tilde{\nu}$ = 2968 (s), 2904 (m), 2869 (m), 2345 (vw), 1734 (vw), 1448 (w), 1420 (m), 1261 (vw), 1205 (s), 1135 (s), 921 (w), 904 (m), 884 (w), 801 (w), 726 (m), 694 (m), 542 (w), 448 (w) cm^{-1}; MS (EI, 70 eV): *m/z* (%) = 226 (14) $[M]^+$, 159 (3) $[M–C_5H_7]^+$, 127 (34) $[M–C_5H_7S]^+$, 99 (92) $[M–C_5H_7S–C_2H_4]^+$, 98 (90) $[C_5H_6S]^+$, 85 (34) $[M–C_5H_7S–C_2H_4–CH_2]^+$, 67 (100) $[C_5H_7]^+$; HRMS (EI, 70 eV): calcd for $C_{12}H_{18}{}^{32}S_2$ $[M]^+$ 226.0844; found 226.0843.

*1,4-Bis(bicyclo[1.1.1]pent-1-ylthio)butane (**13b**)*: **13b** was synthesized from a solution of **1** (general procedure a) according to the general procedure c. The product **13b** was obtained as a colourless liquid in 31% yield (65.0 mg, 255 µmol).

^{1}H NMR (400 MHz, $CDCl_3$): δ = 2.72 (s, 2H, 2 × C*H*), 2.53 (m, 4H, 2 × SCH_2CH_2), 1.96 (s, 12H, 6 × CCH_2CH), 1.68 (m, 4H, 2 × SCH_2CH_2) ppm; ^{13}C NMR (100 MHz, $CDCl_3$): δ = 53.9 (–, 6 × CCH_2CH), 44.7 ($C_{quart.}$, 2 × S*C*), 30.8 (–, 2 × SCH_2CH_2), 29.7 (–, 2 × SCH_2CH_2), 28.8 (+, 2 × *C*H) ppm; IR (ATR): $\tilde{\nu}$ = 2973 (m), 2907 (m), 2871 (m), 1729 (vw), 1447 (w),

1280 (w), 1205 (s), 1139 (m), 902 (w), 741 (vw), 442 (vw) cm^{-1}; MS (EI, 70 eV): *m/z* (%) = 254 (3) $[M]^+$, 155 (23) $[M–C_5H_7S]^+$, 147 (62) $[M–C_5H_7–C_3H_5+H]^+$, 120 (10) $[M–(C_5H_7)_2]^+$, 100 (33) $[C_5H_7S+H]^+$, 99 (63) $[C_5H_7S]^+$, 89 (56) $[M–C_5H_7–C_5H_7S+H]^+$, 87 (63) $[C_4H_7S]^+$, 85 (95) $[M–C_5H_7S–C_4H_8–CH_2]^+$, 67 (85) $[C_5H_7]^+$, 55 (100) $[C_4H_7]^+$; HRMS (EI, 70 eV): $C_{14}H_{22}{}^{32}S_2$ $[M]^+$ 254.1157; found 254.1158.

*1,6-Bis(bicyclo[1.1.1]pent-1-ylthio)hexane (**13c**)*: **13c** was synthesized from a solution of **1** (general procedure a) according to the general procedure c. The product **13c** was obtained as a colourless liquid in 47% yield (38.0 mg, 135 µmol).

^{1}H NMR (400 MHz, $CDCl_3$): δ = 2.71 (s, 2H, 2 × C*H*), 2.52 (m, 4H, 2 × SC*H*$_2$CH$_2$CH$_2$), 1.95 (s, 12H, 6 × CC*H*$_2$CH), 1.59 (m, 4H, 2 × SCH$_2$C*H*$_2$CH$_2$), 1.38 (m, 4H, 2 × SCH$_2$CH$_2$C*H*$_2$) ppm; ^{13}C NMR (100 MHz, $CDCl_3$): δ = 53.8 (–, 6 × C*C*H$_2$CH), 44.7 ($C_{quart.}$, 2 × S*C*), 34.0 (–, 2 × SCH$_2$CH$_2$CH$_2$), 30.4 (–, 2 × SCH$_2$*C*H$_2$CH$_2$), 28.8 (+, 2 × *C*H), 28.1 (–, 2 × SCH$_2$CH$_2$*C*H$_2$) ppm; IR (ATR): $\tilde{\nu}$ = 2974 (w), 2925 (w), 2872 (w), 1727 (vw), 1459 (vw), 1270 (vw), 1206 (m), 1141 (w), 903 (vw), 736 (vw) cm^{-1}; MS (EI, 70 eV): *m/z* (%) = 282 (100) $[M]^+$, 215 (28) $[M–C_5H_7]^+$, 148 (11) $[M–(C_5H_7S)_2]^+$, 100 (46) $[C_5H_7S+H]^+$, 99 (96) $[C_5H_7S]^+$, 87 (29) $[C_4H_7S]^+$, 85 (100) $[M–C_5H_7S–C_6H_{12}–CH_2]^+$, 67 (81) $[C_5H_7]^+$; HRMS (EI, 70 eV): calcd for $C_{16}H_{26}{}^{32}S_2$ $[M]^+$ 282.1470; found 282.1472.

*1-(Phenylsulfoxide)-bicyclo[1.1.1]pentane (**14**)*: In a 10 mL flask 100 mg of **7a** (567 µmol, 1.00 equiv.) were dissolved in 1.0 mL dichloromethane. 87 mg *m*-chloroperoxybenzoic acid (567 µmol, 1.00 equiv.) were added in portions and the mixture was stirred for 5 min at room temperature. The precipitate was filtered off and the filtrate was washed with $Na_2S_2O_3$ solution and 1 M NaOH-solution. The organic phase was dried over Na_2SO_4 and the solvent was removed under reduced pressure. The crude product was purified by column chromatography (SiO_2, cyclohexane/EtOAc, 5:1) to obtain the product **14** as a colourless oil in 71% yield (77.0 mg, 400 µmol).

R_f (SiO_2, cyclohexane/EtOAc, 5:1): 0.18; ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.53–7.47 (m, 5H, Ar-H), 2.81 (s, 1H, C*H*), 1.88 (s, 6H, 3 × C*H*$_2$) ppm; ^{13}C NMR (100 MHz, $CDCl_3$) δ = 141.7 (C_{quart}, *C*$_{Ar}$), 130.9 (+, *C*H$_{Ar}$), 129.0 (+, 2 × *C*H$_{Ar}$), 124.3 (+, 2 × *C*H$_{Ar}$), 55.4 (C_{quart}, C$_{Ar}$S*C*), 49.9 (–, 3 × *C*H$_2$), 27.8 (+, *C*H) ppm; IR (ATR): $\tilde{\nu}$ = 3462 (vw), 2970 (w), 2917 (w), 2880 (w), 1581 (vw), 1476 (w), 1443 (w), 1303 (vw), 1201 (m), 1129 (w), 1084 (m), 1067 (w), 1036 (m), 997 (m), 883 (w), 869 (w), 777 (w), 746 (m), 692 (m), 555 (m), 511 (m), 484 (m) cm^{-1}; MS (EI, 70 eV): *m/z* (%) = 192 (2) $[M]^+$, 126 (100) $[M–C_5H_7+H]^+$, 125 (10) $[M–C_5H_7]^+$, 78 (41) $[C_6H_5+H]^+$, 77 (15) $[C_6H_5]^+$, 67 (61) $[C_5H_7]^+$; HRMS (EI, 70 eV): calcd for $C_{11}H_{12}O^{32}S$ $[M]^+$ 192.0609; found 192.0610.

*1-(Phenylsulfonyl)-bicyclo[1.1.1]pentane (**15**)*: In a 10 mL flask 200 mg of **7a** (1.13 mmol, 1.00 equiv.) were dissolved in 2.0 mL dichloromethane. 690 mg *m*-chloroperoxybenzoic acid (4.54 mmol, 4.00 equiv.) were added in portions and the mixture was stirred for 5 min at room temperature. The precipitate was filtered off and the filtrate was washed with $Na_2S_2O_3$ solution and 1 M NaOH-solution. The organic phase was dried over Na_2SO_4 and the solvent was removed under reduced pressure to obtain the product **15** as a colourless oil in 69% yield (162 mg, 779 µmol).

^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.87–7.84 (m, 2H, Ar-H), 7.67–7.63 (m, 1H, Ar-H), 7.58–7.54 (m, 2H, Ar-H), 2.72 (s, 1H, C*H*), 2.08 (s, 6H, 3 × C*H*$_2$) ppm; ^{13}C NMR (100 MHz, $CDCl_3$) δ = 134.2 (C_{quart}, *C*$_{Ar}$), 133.6 (+, 2 × *C*H$_{Ar}$), 128.9 (+, 2 × *C*H$_{Ar}$), 127.6 (+, *C*H$_{Ar}$), 54.1 (–, 3 × *C*H$_2$), 45.8 (C_{quart}, C$_{Ar}$S*C*), 28.8 (+, *C*H) ppm; IR (ATR): $\tilde{\nu}$ = 2996 (w), 2918 (w), 2884 (w), 1584 (vw), 1479 (vw), 1446 (m), 1301 (s), 1205 (m), 1177 (m), 1130 (s), 1078 (m), 1022 (w), 998 (w), 940 (w), 898 (w), 876 (m), 779 (w), 759 (m), 719 (m), 689 (m), 612 (s), 564 (m), 534 (m) cm^{-1}; MS (EI, 70 eV): *m/z* (%) = 209 (1) $[M+H]^+$, 208 (2) $[M]^+$, 191 (2) $[M–OH]^+$, 143 (27) $[M–C_5H_6+H]^+$, 125 (51) $[M–O–C_5H_7]^+$, 77 (24) $[C_6H_5]^+$, 67 (100) $[C_5H_7]^+$; HRMS (EI, 70 eV): calcd for $C_{11}H_{12}{}^{32}S$ $[M]^+$ 176.0654; found 176.0655.

*Bicyclo[1.1.1]pent-1-yl(phenyl)selane (**17**)*: **17** was synthesized from a solution of **1** (general procedure b) according to the general procedure c. Instead of a thiol benzeneselenol (**16**) was added as a 1 M solution in diethyl ether. The product **17** was obtained as a yellow liquid in quantitative yield (133 mg, 596 µmol).

^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.57–7.54 (m, 2H, Ar-H), 7.30–7.25 (m, 3H, Ar-H), 2.96 (s, 1H, C*H*), 2.00 (s, 6H, 3 × C*H*$_2$) ppm; ^{13}C NMR (100 MHz, $CDCl_3$): δ = 135.4 (+, 2 × *C*H$_{Ar}$), 131.7 ($C_{quart.}$, *C*$_{Ar}$), 128.9 (+, 2 × *C*H$_{Ar}$), 127.6 (+, *C*H$_{Ar}$), 55.4 (–, 3 × *C*H$_2$), 38.9 ($C_{quart.}$, C$_{Ar}$Se*C*), 31.0 (+, *C*H) ppm; IR (ATR): $\tilde{\nu}$ = 3056 (vw), 2962 (w), 2909 (w), 2874 (w), 1577 (w), 1475 (m), 1436 (w), 1299 (w), 1204 (m), 1117 (m), 1072 (w), 1021 (w), 999 (w), 883 (m), 735 (m), 690 (m), 671 (w), 471 (w) cm^{-1}; MS (EI, 70 eV): *m/z* (%) = 224/222/220 (18/19/5) $[M]^+$, 158 (21) $[M–C_5H_7+H]^+$, 157 (20) $[M–C_5H_7]^+$, 78 (33) $[C_6H_5+H]^+$, 77 (41) $[C_6H_5]^+$, 67 (100) $[C_5H_7]^+$; HRMS (EI, 70 eV): calcd for $C_{11}H_{12}{}^{80}Se$ $[M]^+$ 224.0104; found 224.0104.

Acknowledgements

We greatly acknowledge the contribution of the precursor 1,1-dibromo-2,2-bis(chloromethyl)cyclopropane (**3**) by abcr GmbH. R.M.B. acknowledges the SFB 1176 funded by the German Research Council (DFG) in the context of project B3 for funding.

Keywords: [1.1.1]propellane • bicyclo[1.1.1]pentane • thiols • hydrogen sulfide • amino acid

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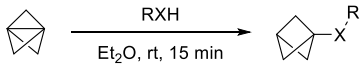
A versatile tool for new building blocks. Thiols can open [1.1.1]propellane in simple, clean and fast reactions with good functional group tolerance. Even hydrogen sulfide, amino acids and selenols can be used in this radical reaction. The products can be further modified to tune the polarity. This reaction can potentially be applied in material modifications, bioconjugations or in the synthesis of new medicinal chemistry building blocks.



X = S, Se; R = alkyl, aryl, H

*Robin M. Bär, Stefan Kirschner, Martin Nieger, Stefan Bräse**

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Alkyl and aryl thiol addition to [1.1.1]propellane – scope and limitations of a fast conjugation reaction

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