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PII: S0040-4039(13)01312-9
DOI: http://dx.doi.org/10.1016/j.tetlet.2013.07.144
Reference: TETL 43342

To appear in: *Tetrahedron Letters*

Received Date: 21 May 2013

Please cite this article as: Gschneidtner, T.A., Moth-Poulsena, K., A photolabile protection strategy for terminal alkynes, *Tetrahedron Letters* (2013), doi: http://dx.doi.org/10.1016/j.tetlet.2013.07.144

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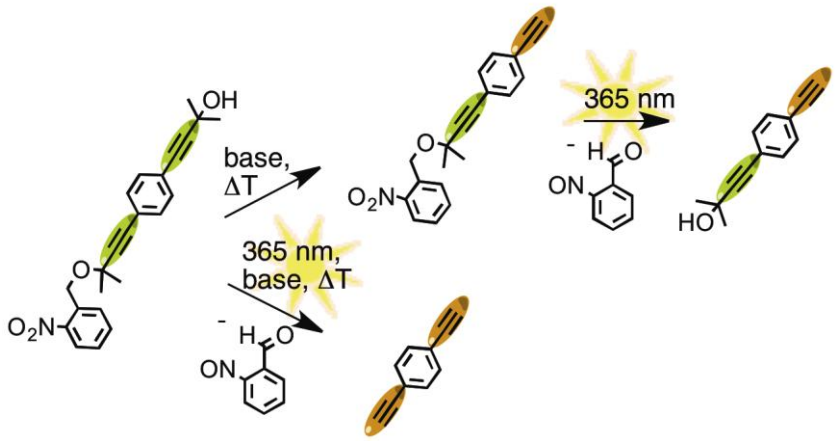

Tetrahedron Letters
journal homepage: www.elsevier.com

A photolabile protection strategy for terminal alkynes

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ARTICLE INFO

Article history:
Received
Received in revised form
Accepted
Available online

Keywords:
Photolabile protection
Terminal alkynes
o-nitrobenzyl

ABSTRACT

We present a strategy for photolabile protection of terminal alkynes. Several photo-caged alcohols were synthesized via mild copper(II)-catalyzed substitution between tertiary propargylic alcohols and 2-nitrobenzyl alcohol to build up robust, base stable *o*-nitrobenzyl (NB) photo-cleavable compounds. We compare the new photolabile protecting group with the commonly used alkyne protecting group, 2-methyl-3-butyn-2-ol and the results show that NB ethers are stable under the cleaving conditions for the cleavage of methylbutynol protected alkynes. Additionally, we present the synthesis of photo-cleavable NB derivatives containing thiol groups that can serve as agents for photoinduced surface functionalization reactions.

Terminal alkynes are reactive species in a number of important chemical reactions such as the 1,3-dipolar cycloaddition[1] between azides and alkynes to give 1,2,3-triazoles (click-chemistry[2]), the Sonogashira reaction and its forerunner, the Stephens-Castro reaction.[3,4] Furthermore, alkynes can undergo the Vollhardt cyclization,[5] alkyne trimerization to form aromatic compounds,[6,7] or can act as dienophiles in Diels-Alder reactions.[8] A number of protecting groups have been developed for alkyne chemistry such as trialkylsilyl, benzyl- or phenyl-substituted alkylsilyl groups and propargylic alcohols. The development of a photolabile protecting group for terminal alkynes has, to the best of our knowledge, not been described in the literature until now, and would add to the portfolio of possible chemical transformations of terminal alkynes. Such protected alkynes could also be applied in the modification of surfaces where it is highly desirable to perform spatially controlled chemoselective reactions, e.g., by using chemoselective "click chemistry".[9]

Protected, photolabile compounds, the so called caged compounds,[10] have been used in organic synthesis,[11–13] surface science[14,15] and biochemistry,[16] for DNA-chip fabrication,[17,18] natural product synthesis,[19] and the photorelease of biological substances.[20] Among photo-cleavable groups such as the nitroindoline (Bni) group,[21,22] (coumarin-4-yl) methyl derivatives[23,24] and *p*-hydroxyphenacyl derivatives,[25,26] the *o*-nitrobenzyl (NB)[27–29] group is a very robust and a widely used group for the protection of primary alcohols.[27] Photoinduced reactions of NBs were reported as early as 1901.[30] The first ~~reported~~ use of the *o*-nitrobenzyl group as a protecting group for benzoic acid was by Barltrop et al.[31] in 1966, and it was further developed by Kaplan et al.,[16] who used it for the triggered release of ATP. Photolysis of *o*-nitrobenzyl-derived ethers releases the free alcohol and *o*-nitrosobenzaldehyde, due to proton abstraction by the light-activated nitro group from the benzylic ether.[13,27,32] NBs are used to release, e.g., phosphoric acids,[33–35] thiols,[36] amines,[37] carboxy acids,[38,39] and alcohols,[29] and internal alkynes[40] via light activation. For an overview of this field we refer to a review.[41]

Herein, we introduce a photolabile protection strategy for terminal alkynes based on a combination of the photoactive NB group and tertiary propargyl ethers. The combined NB-propargyl ether groups are stable under strong alkaline conditions but release terminal alkynes after irradiation under alkaline conditions (Scheme 1).

A library of alkynes protected with the NB cage on the tertiary propargylic alcohol was synthesized (Table 1, compounds **1**-**7**). 2-Methyl-3-butyn-2-ol was introduced by a standard Sonogashira[4] reaction with precursor molecules (aryl halides)[42] **8**, **9** and **12**-**14** with 2-methyl-3-butyn-2-ol. These products were converted into the NB-propargylic ethers **1**-**7** via a copper-catalyzed nucleophilic substitution reaction with *o*-nitrobenzyl alcohol. In this step the tertiary propargylic alcohol was activated with $CuBr_2$ to react with *o*-nitrobenzyl alcohol at room temperature.

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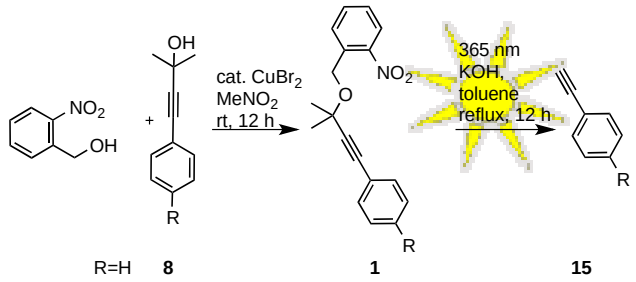


Scheme 1. Final step in the synthesis of *o*-nitrobenzyl NB compounds. *o*-Nitrobenzyl alcohol reacts with different tertiary propargylic alcohols in the presence of catalytic amounts of $CuBr_2$. These products can be photo-cleaved under alkaline conditions to give terminal alkynes.

Propargylic ethers are interesting building blocks in organic chemistry[43,44] and terminal and secondary propargylic ethers have been prepared using Lewis acids,[45,46] or transition metal complexes with, e.g. cobalt (the Nicholas reaction),[47] rhenium,[43,48] or ruthenium.[49] However, mild methods for tertiary ethers are rare, since their synthesis is not trivial. A mild method recently reported by Huang et al.[50] has been used in this study to form the propargylic ether via a mild copper(II)-catalyzed (S_N1) substitution.

The obtained photolabile NB-propargylic ethers were deprotected via irradiation (365 nm, 200 µW/cm^2) to form the alcohols **8**-**14** and the terminal alkynes **15**-**19** under alkaline conditions. Figure 1 illustrates an example of the photo-cleaving reaction of 1-[(2-methyl-4-phenylbut-3-yn-2-yl)oxy]-2-nitrobenzene (**1**) in $CDCl_3$ monitored by ^{1}H NMR spectroscopy. The sample was irradiated over a period of 120 minutes interrupted by short breaks, in which the NMR spectra (10-minute intervals) were recorded. The conversion of the starting material (signal **a**, **e**) as well as the formation of the two characteristic products *o*-nitrosobenzaldehyde (signals **c**, **d**) and 2-methyl-4-phenylbut-3-yn-2-ol (signal **b**) were monitored. The disappearance of the benzylic proton (**e**) as well as a shift of the protons of the methyl group of 2-methylbut-3-yn-2-ol (**a** to **b**), indicated the change from an ether to a free alcohol.

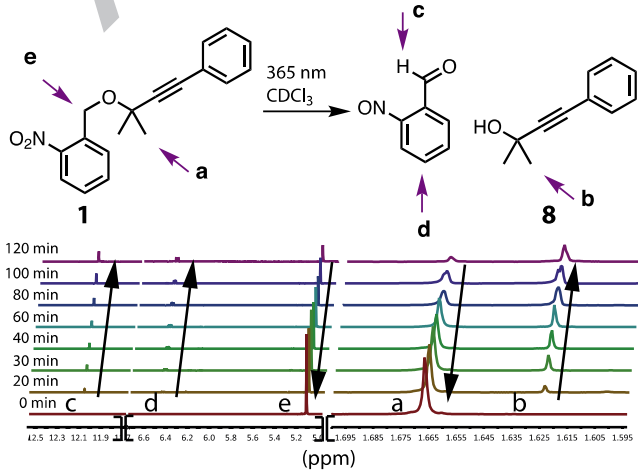
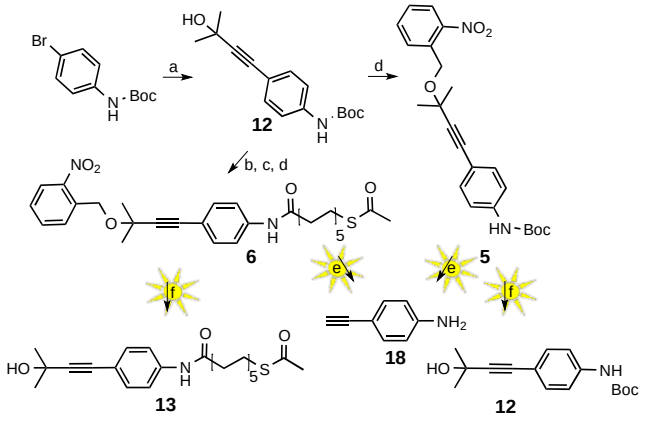


Figure 1. ^{1}H-NMR spectra of **1** in $CDCl_3$ upon irradiation with UV-light (365 nm, 200 µW/cm^2) for 120 minutes. The formation of **8** and the by-product 2-nitrosobenzaldehyde (Lit. values NMR[32]) were observed.

The versatility of the copper-catalyzed reaction using tertiary propargylic alcohols to build up NB-propargylic photo-caged derivatives was also tested on alkynes containing functional groups, such as ethers (**7**) or carbamates (**5**, **6**) (Table 1). For subsequent modification reactions, amine (**5**) bromide (**2**) and alkyne functionalities (**4**) were introduced. These functional groups can react, e.g., via cross-coupling reactions, peptide-coupling strategies or N-alkylation reactions among others. The synthesis of **3** from **2** via the Sonogashira reaction underlines the tolerance of the NB group and further modification possibilities (see Scheme 4).

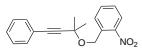
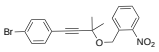
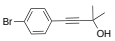
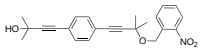
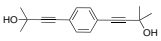
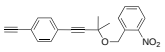
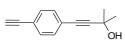
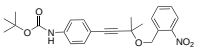
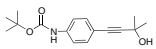
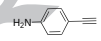
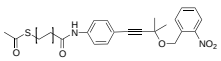
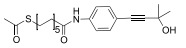
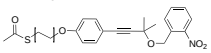
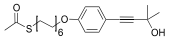
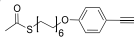
A wide variety of photo-cleavable derivatives and their further use can be envisioned. As a proof of principle we synthesized the surface active compounds **6** and **7** (see Schemes 2 and 3) that can be applied for self-assembly on gold surfaces and spatially controlled photoinduced reactions. In the first step, *tert*-butyl [4-(3-hydroxy-3-methylbut-1-yn-1-yl)phenyl]carbamate (**12**) was obtained via Pd-catalyzed reaction of 1-bromo-4-*tert*-butoxycarbonylaminobenzene and 2-methylbut-3-yn-2-ol (Scheme 2). Compound **12** was deprotected with tetra-*n*-butyl ammonium fluoride (TBAF) to give the free amine.[51] An activated N-C coupling strategy (EDC and DMAP, as used in peptide synthesis) was used to react 11-(acetylthio)undecanoic acid (synthesized according to published procedures[52]) with **12** to give **6**. Irradiation under neutral conditions deprotected **6** and led to the release of alcohol **13**. Irradiation under alkaline conditions (365 nm, 200 µWatt/cm^2, in aq. KOH, toluene) hydrolysed the amide-functionality of photo-caged **6** to give **18**, thus the thiol linker for the gold surface was lost. As a consequence of the limited stability of compound **6** under basic conditions a more stable derivative using an ether instead of an amine (**7**) was designed (Scheme 3).

Substrate **7** was synthesized via protection of the alcohol moiety of 4-bromophenol with 3,4-dihydro-2*H*-pyran under weakly acidic conditions (*p*-TsOH) followed by a Sonogashira reaction to form **25**. Tetrahydropyran **25** was deprotected to give the free alcohol under acidic conditions and compound **7** was reacted via etherification with *S*-(12-bromododecyl) thioacetate (**22**) (Scheme 3). The NB ether was deprotected by irradiation under alkaline conditions to form the terminal alkyne **19**. Thus, we have shown that it is possible to obtain terminal alkynes with a thiol functionality for self-assembly on gold surfaces.

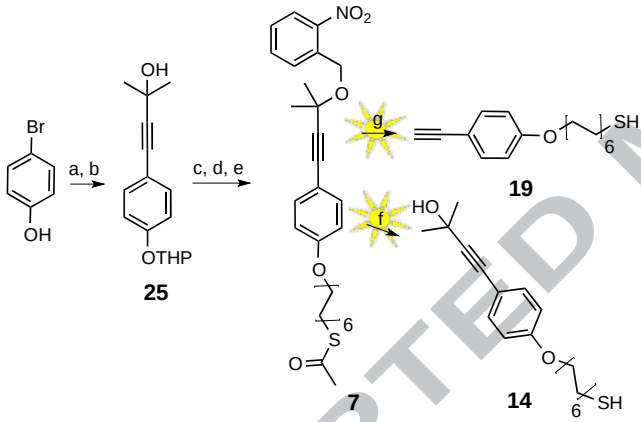


Scheme 2. Synthesis of photolabile compounds **5** and **6**. **a.** $PdCl_2(PPh_3)_2$, NEt_3, 2-methyl-3-butyn-2-ol, CuI, PPh_3,THF; **b.** TBAF, THF; **c.** EDC, DMAP, DMF, 11-(acetylthio) undecanoic acid; **d.** $CuBr_2$, $MeNO_2$, *o*-nitrobenzyl alcohol; **e.** 365 nm, KOH, toluene, **f.** 365 nm, ethyl acetate.

Table 1. Library of photolabile compounds synthesized as shown in Scheme 1.

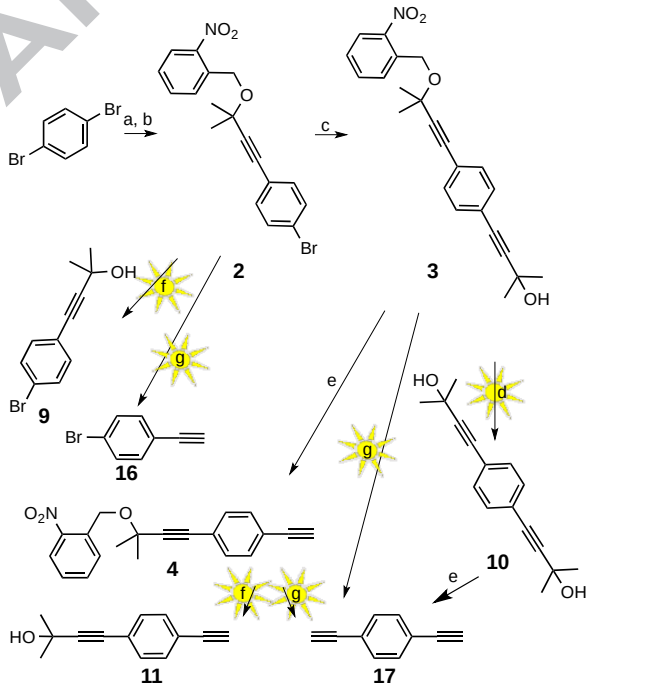
Photolabile Compounds		Photoreaction		Alkaline Photoreaction	
1 (70%)		**8** (96%)		**15** (16 h, 70%)	
2 (73%)		**9** (94%)		**16** (5 h, 78%)	
3 [a]		**10** (86%)		**17** (12 h, 70%)	
4 [b]		**11** (88%)		**17** (12 h, 62%)	
5 (57%)		**12** (90%)		**18** (10 h, 50%)	
6 (42%)		**13** (92%)		- (0%)	
7 (48%)		**14** (94%)		**19** (14h, 52%)	

All compounds were deprotected to the propargylic alcohol in $CHCl_3$ in 120 minutes, after irradiation with photons of 365 nm wavelength and 200 μW/cm^2 intensity. Upon UV-irradiation under alkaline conditions (KOH in toluene (reflux), 5-14 h, see above) these compounds formed terminal alkynes. [a]Synthesized from compound **2**, [b]Obtained via deprotection of **3**.



Scheme 3. Synthesis of an alkyne functionalized linker for surfaces, **19**, as well as its photolabile precursor **7**. **a.** *p*-TsOH, DCM, 3,4-dihydro-*2H*-pyran; **b.** $PdCl_2(PPh_3)_2$, NEt_3, 2-methyl-3-butyn-2-ol, CuI, PPh_3,THF; **c.** *p*-TsOH, THF/MeOH; **d.** K_2CO_3, DMF, *S*-(12-bromododecyl) thioacetate; **e.** $CuBr_2$, $MeNO_2$, *o*-nitrobenzyl alcohol, **f.** 365 nm, ethyl acetate, **g,** 365 nm, KOH, toluene.

To demonstrate the use of the photolabile protecting group for terminal alkynes in synthetic organic chemistry, we compared a conventional 2-methyl-3-butyn-2-ol protected alkyne with the NB ether protected compound (Scheme 4). We synthesized compound **3**, which contains both the propargylic alcohol protecting group for alkynes and the photo-caged propargylic alcohol. To achieve this, 1,4-dibromobenzene was reacted with 2-methyl-3-butyn-2-ol and *o*-nitrobenzyl alcohol was introduced to form photo-caged **2**. This was transformed into **3** by Sonogashira reaction in the dark at 80 °C, which demonstrates the high stability of this photolabile compound. Alcohol **3** was then deprotected to give **4** under basic conditions (KOH, toluene, reflux, dark), leaving the photolabile group intact. Additionally, **3** was deprotected with UV light (365 nm) to form **10** and irradiation under alkaline conditions gave the terminal alkyne **17**. We showed that the propargylic alkyne protecting group was removed under traditional alkaline deprotection conditions, while the NB-propargylic protected alcohol group stayed intact in all cases.



Scheme 4. Synthesis of the photolabile *ortho*-protecting group **3** and a bromo-substituted photo-caged **2**. **a.** $PdCl_2(PPh_3)_2$, NEt_3, 2-methyl-3-butyn-2-ol, CuI, PPh_3, THF; **b.** $CuBr_2$, $MeNO_2$ *o*-nitrobenzyl alcohol; **c.** $PdCl_2(PPh_3)_2$, NEt_3, 2-methyl-3-butyn-2-ol, CuI, PPh_3, THF; **d.** 365 nm, ethylacetate; **e.** KOH, toluene, **f.** 365 nm, ethyl acetate; **g.** 365 nm, KOH, toluene.

In summary, we have developed a method to synthesize tertiary propargylic ether NB-photo-cages, which can release terminal alkynes upon UV-irradiation under alkaline conditions. These photo-protected propargylic alcohols add to the portfolio of alkyne protecting groups, and we envision their possible use in synthetic organic chemistry. The new light-sensitive protection strategy was applied to synthesize functional photo-cages that can be used for further post-modification reactions. The presented thiol-functionalized photocages may serve as agents for chemoselective, site-specific surface modification reactions on metal surfaces in future investigations.

Acknowledgments

This work was funded by Chalmers Materials Area of Advance.

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Supplementary Material

Supplementary data associated with this article can be found, in the online version, at….

A photo labile protection strategy for terminal alkynes

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Supporting Information:

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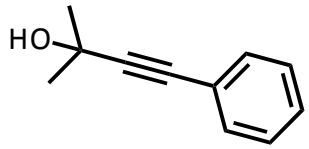
General Methods:

Characterization. Nuclear magnetic resonance (**NMR**) measurements were recorded by an automated Agilent (Varian) MR 400 MHz spectrometer, equipped with "one-probe" (^{1}H-Frequency: 399.95 MHz and ^{13}C-Frequency: 100.58 MHz) in $CDCl_3$ as the solvent or on a Varian Unity 500. Chemical shifts (δ) are given in ppm referring to the signal center using the solvent peak for reference: $CDCl_3$ 7.26 ppm/77.0 ppm. **UV/Vis-absorption** spectra were measured using a Varian Cary 5000 spectrometer. The **irradiation** experiments were performed with a UV-lamp with 365 nm wavelength and an intensity of 200 µW/cm^2. **HRMS** (ESI+/-) was measured on a LC Agilent 1000 gradient pump, Autosampler CTC PAL, Mass spectrometer Micromass Q-TOF micro (water) spectrometer at Stenagen Analysislab AB, Sweden. All samples on the LC Agilent 1000 gradient were prepared by dissolving 1 mg in 1 mL of acetonitrile (ACN). 5µl were injected on a C18 LC system (Agilent XDB-C18 1.8 um 2.1x50 mm, flow rate 0.4 ml/min, gradient 5-95% ACN/water with 0.1% formic acid). Some samples were recorded on a Bruker Autoflex apparatus at the department of Chemistry at the University at Copenhagen, in methanol.

Materials. Solvents and reagents were obtained from Sigma-Aldrich (Steinheim, Germany) except 2-nitrobenzyl alcohol, which was purchased from ABCR (Karlsruhe, Germany). THF was distilled from sodium/benzophenone shortly prior use. All other dry solvent were purchased from Aldrich chemical company and used as received.

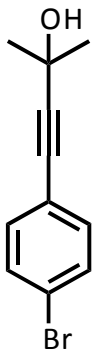
SI-1 Synthesis and Characterization of Compounds 8-14



2-methyl-4-phenylbut-3-yn-2-ol (8) was synthesized according to published procedures in a slightly modified procedure.[8]

2-methylbut-3-yn-2-ol (3.21 g, 38.16 mmol) and 15 mL NEt_3 were added to a mixture of bromobenzene (5.00 g, 31.8 mmol), CuI (181 mg, 954 µmol), PPh_3 (996 mg, 3.80 mmol), and $PdCl_2(PPh_3)_2$ (1.34 g, 1.90 mmol) under nitrogen. The reaction mixture was heated to 80 °C for 12 h. The reaction was quenched with water (100 mL), extracted with dichloromethane (DCM) (3 x 100 mL). The combined organic phase was dried over $MgSO_4$, filtered off, and concentrated under reduced pressure. The product was obtained as a yellow oil by column chromatography (silica, hexane/ethyl acetate (4:1), R_f=0.33) (yield: 4.84 g, 95%).

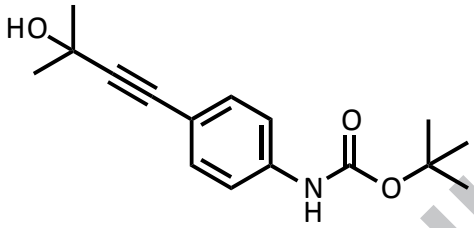
IR (KBr pellet): (Lit.[9]) $_{max}$ (cm^{-1}): 3351 (O-H stretch), 3082 (C-H stretch, aromatic), 3057 (C-H stretch, aromatic), 3035 (C-H stretch, aromatic), 2982 (C-H stretch, alkyl), 2933 (C-H stretch, alkyl), 2230 (C≡C stretch), 1598 (C-C stretch, aromatic), 1573 (C-C stretch, aromatic), 1489 (C-C stretch, aromatic), 1444 (C-C stretch aromatic), 1376 (C-H, alkyl), 1362 (C-H, alkyl), 1272, 1162 (C-O stretch); **^{1}H-NMR** (400 MHz, $CDCl_3$, 298 K): δ_H (ppm): 7.44-7.39 (m, 2H, $H_{arom.}$), 7.32-7.27 (m, 3H), 1.62 (s, 6H) (cf. Lit.[10]); **^{13}C-NMR** (101 MHz, $CDCl_3$, 298 K): δ_C (ppm): 131.5, 128.1, 122.6 ($C_{quart.}$), 93.6 (C_{alkyne}), 81.9 (C_{alkyne}), 65.4 ($C_{quart.}$/$_{t\text{-}Bu}$), 31.3 (CH_3) (cf. Lit.[11]); **UV/VIS** ($CHCl_3$): λ_{max} (nm), (log ε_λ ($M^{-1}cm^{-1}$)): 269, (4.35).



4-(4-bromophenyl)-2-methylbut-3-yn-2-ol (9)

2-methylbut-3-yn-2-ol (713 mg, 8.48 mmol), NEt_3 (15 mL), and THF (15 mL) were added to a mixture of 1,4-dibromobenzene (2.00 g, 8.48 mmol), CuI (97 mg, 509 µmol), PPh_3 (133 mg, 509 mmol), and $PdCl_2(PPh_3)_2$ (179 mg, 255 µmol) under nitrogen. The reaction mixture was heated to 75 °C for 12 h. The reaction was quenched with water (50 mL) and the crude product extracted with DCM (3 x 50 mL). The combined organic phase was dried over $MgSO_2$, filtered off, and dried under vacuum. The product was obtained as a yellow oil by column chromatography (silica, hexane/ethyl acetate (4:1), R_f=0.57) (yield: 1.09 g, 54%).

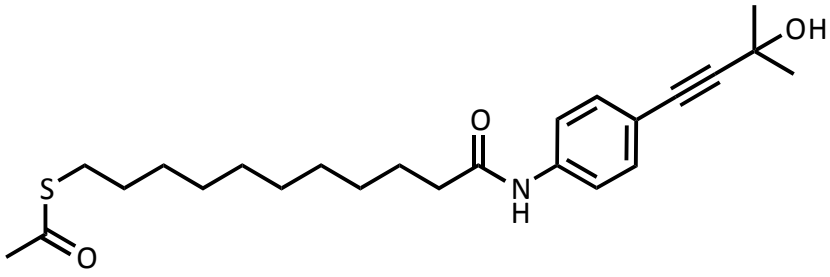
IR (KBr pellet): $_{max}$ (cm^{-1}): 2982 (C-H stretch, alkyl), 2929 (C-H stretch, alkyl), 2971 (C-H stretch, alkyl), 1510 (C-C stretch, aromatic), 1370 (C-H, alkyl), 1280, 1171 (C-O stretch, tertiary alcohol); **UV/VIS** ($CHCl_3$): λ_{max} (nm), (log ε_λ ($M^{-1}cm^{-1}$)): 251, (4.13); 261, (3.94); **^{1}H-NMR** (400 MHz, $CDCl_3$, 298 K): δ_H (ppm): 7.43 (m, 2H, $H_{arom.}$), 7.27 (m, 2H, $H_{arom.}$), 1.61 (s, 6H, CH_3) (cf. Lit.[13]); **^{13}C-NMR** (101 MHz, $CDCl_3$, 298 K): δ_C (ppm): 133.2, 131.6, 122.6 ($C_{quart.}$), 121.8 ($C_{quart.}$), 95.1 (C_{alkyne}), 81.2 (C_{alkyne}), 65.7 ($C_{quart.}$/$_{t\text{-}Bu}$), 31.5 (CH_3) (cf. Lit.[13]).



***tert*-butyl (4-(3-hydroxy-3-methylbut-1-yn-1-yl)phenyl)carbamate (12)**

2-methylbut-3-yn-2-ol (370 mg, 4.41 mmol) and NEt_3 (5 mL)were added to a mixture of 1-bromo-4-*t*-butoxycarbonylaminobenzene (1 g, 3.67 mmol), CuI (71.6 mg, 370 µmol), PPh_3 (115 mg, 440 µmol), and $PdCl_2(PPh_3)_2$ (154 mg, 220 µ mol) under nitrogen. The reaction was heated to 80 °C and stirred for 12 h. The reaction mixture was quenched with water (50 mL) and extracted with DCM (3 x 50 mL). The combined organic phase was dried over $MgSO_2$, filtered off, and concentrated under vacuum. The product was obtained as a yellow oil by column chromatography (silica, DCM/EA (10:1), R_f=0.26) (yield: 889 mg, 88%).

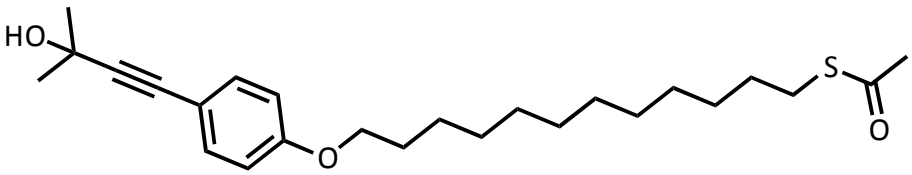
IR (KBr pellet): $_{max}$ (cm^{-1}): 3447 (O-H stretch, N-H stretch), 2980 (C-H stretch, alkyl), 2935 (C-H stretch, alkyl), 2823 (C-H stretch, alkyl), 2229 (C≡C stretch), 1704 (C=O stretch, carbonyl amide), 1610, 1590 (C-C stretch, aromatic), 1520 (N-C=O stretch, amide), 1393 (C-H, alkyl), 1367 (C-H, alkyl), 1159 (C-O stretch, tertiary alcohol); **^{1}H-NMR** (400 MHz, $CDCl_3$, 298 K): δ_H (ppm): 7.32 (m, 4H, $H_{arom.}$), 6.57 (s, broad, 1H, H_{amide}), 2.12 (s, broad, 1H, OH), 1.60 (s, 6H, CH_3), 1.51 (s, 9H, $H_{t\text{-}Bu/BOC}$); **^{13}C-NMR** (101 MHz, $CDCl_3$, 298 K): δ_C (ppm): 152.4 ($C_{quart./carbonyl}$), 138.4 ($C_{quart.}$), 132.4, 118.0 ($C_{quart.}$), 116.9 ($C_{quart.}$), 92.9 (C_{alkyne}), 81.9 (C_{alkyne}), 80.9 ($C_{quart./t\text{-}Bu/BOC}$), 65.6 ($C_{quart.}$/$_{t\text{-}Bu}$), 31.5 ($CH_3$), 28.3 ($CH_3$); **UV/VIS** ($CHCl_3$): λ_{max} (nm), (log ε_λ ($M^{-1}cm^{-1}$)): 267, (4.15); **HR/ESI-Mass** m/z (MeOH): $[C_{16}H_{21}NO_3+Na]^+$: calc.: 298.1414 $[M+Na]^+$, exper. 298.1419.



***S*-(11-((4-(3-methyl-3-((2-nitrobenzyl)oxy)but-1-yn-1-yl)phenyl)amino)-11-oxoundecyl) ethanethioate (13)**

11-(acetylthio)undecanoic acid (**20**) (557 mg, 2.14 mmol) was stirred with 1-ethyl-3-(3-dimethylaminopropyl)carbodiimide (EDC) (410 mg, 2.14 mmol) and 4-dimethyl-aminopyridine (DMAP) (174 mg, 1.43 mmol) in DMF (20 mL) for 20 min at room temperature. 4-(4-aminophenyl)-2-methylbut-3-yn-2-ol (**21**) (250 mg, 1.43 mmol) was added and the reaction mixture was stirred for 12 h. The reaction was quenched with water (50 mL) and the crude product extracted with DCM (3 x 30 mL), dried over $MgSO_4$, filtered off, and concentrated under reduced pressure. **13** was obtained after column chromatography (silica, gradient hexane/ethyl acetate (4:1), (1:1), R_f (hexane/ethyl acetate 4:1)= 0.42) (yield: 555 mg, 93%, yellowish oil).

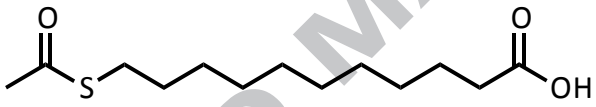
IR (KBr pellet): $_{max}$ (cm^{-1}): 3430 (O-H stretch, N-H stretch), 3200 (O-H stretch), 3096 (C-H stretch, aromatic), 3050 (C-H stretch, aromatic), 2981 (C-H stretch, alkyl), 2928 (C-H stretch, alkyl), 2852 (C-H stretch, alkyl), 2231 (C≡C stretch), 1690 (S-C=O stretch, amine), 1664 (C=O stretch, amide), 1598 (C-C stretch, aromatic), 1535 (C-C stretch, aromatic), 1512 (C-C stretch, aromatic), 1361 (C-H, alkyl), 1244 (S-C stretch), 1164 (C-O stretch, tertiary alcohol); **^{1}H-NMR** (400 MHz, $CDCl_3$, 298 K): δ_H (ppm): 7.47 (d, 2H, $^3J_{HH}$=8.5 Hz, $H_{arom.}$), 7.35 (d, 2H, $^3J_{HH}$=8.5 Hz, $H_{arom.}$), 2.85 (m, 2H), 2.33 (t, 2H, $^3J_{HH}$=9.6 Hz), 2.32 (s, 3H, CH_3), 2.08 (s, br., 1H, OH or NH), 2.04 (s, br., 1H, OH or NH). 1.71 (m, 2H), 1.61 (s, 6H, CH_3), 1.55 (m, 2H), 1.28 (m, 12H); **^{13}C-NMR** (101 MHz, $CDCl_3$, 298 K): δ_C (ppm): 196.4 ($C_{quart./SCO}$), 171.6 ($C_{quart./carbonyl}$), 138.2 ($C_{quart.}$), 132.6, 119.4, 93.5 (C_{alkyne}), 82.0 (C_{alkyne}), 65.8 ($C_{quart./t\text{-}Bu}$), 31.7, 30.8, 29.6, 29.6, 29.5, 29.3, 29.3, 28.9, 25.6, 25.2; **UV/VIS** ($CHCl_3$): λ_{max} (nm), (log ε_λ ($M^{-1}cm^{-1}$)): 273, (4.04); **HR/ESI-Mass** m/z (MeOH): $[C_{24}H_{35}NO_3S+Na]^+$: calc.: 440.2230 $[M+Na]^+$, exper. 440.2235.



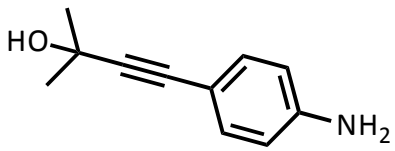
***S*-(12-(4-(3-hydroxy-3-methylbut-1-yn-1-yl)phenoxy)dodecyl) ethanethioate (14)**

4-(3-hydroxy-3-methylbut-1-yn-1-yl)phenol **(23)** (430 mg, 2.44 mmol) and *S*-(12-bromododecyl) thioacetate **(22)** (1.58 mg, 4.88 mmol) were stirred with K_2CO_3 (1.69 mg, 12.2 mmol) in DMF (25 mL) for 16 h at 90 °C. The reaction mixture was

washed with water (3 x 50 mL) and extracted with DCM (3 x 40 mL). The combined organic phase was dried over $MgSO_4$, filtered off, and concentrated under reduced pressure. **22** was obtained as a white solid after column chromatography (silica, hexane/ethyl acetate (4:1), R_f=0.55) (yield: 868 mg, 85%).
IR (KBr pellet): $_{max}$ (cm^{-1}): 3460 (OH stretch), 3173 (C-H stretch, aromatic), 2983 (C-H stretch, alkyl), 2925 (C-H stretch, alkyl), 2852 (C-H stretch, alkyl), 2220 (C≡C stretch), 1692 (C=O stretch, thioacetate), 1606, 1509, 1468, 1354 (C-H, alkyl),
1246 (C-O-C stretch, ether), 1169 (C-O-C stretch, ether), 1135 (C-O-X stretch, ether/alcohol), 1076 (C-O-X stretch, ether/alcohol); **UV/VIS** ($CHCl_3$): λ_{max} (nm), (log ε_λ ($M^{-1}cm^{-1}$)): 257, (4.50); **^{1}H-NMR** (400 MHz, $CDCl_3$, 298 K): δ_H (ppm): 7.34 (d, 2H, $^3J_{HH}$ = 8.8 Hz, $H_{arom.}$), 6.81 (d, 2H, $^3J_{HH}$ = 7.7 Hz, $H_{arom.}$), 3.94 (t, 2H, $^3J_{HH}$= 6.8 Hz, $C_{arom.}$-O-*C*), 3.49 (methanol), 2.86 (m, 4H), 2.32 (s, 3H, CH_3), 1.78 (tt, 2H, $^3J_{HH}$=8.4 Hz, $^4J_{HH}$=6.0 Hz), 1.53 (m, 10H, CH_2+$C_{t\text{-}Bu}$), 1.26 (m, 12H, CH_2); **^{13}C-NMR** (101 MHz, $CDCl_3$, 298 K): δ_C (ppm): 195.9 ($C_{quart./SCO}$), 159.1 ($C_{quart.}$), 133.0, 114.6, 114.3 ($C_{quart.}$), 89.3 (C_{alkyne}), 84.16 (C_{alkyne}), 70.9 ($C_{quart./t\text{-}Bu}$), 68.0 ($C_{arom.}$-O-*C*), 64.6, 50.4 (methanol), 32.2, 30.6, 29.7, 29.5, 29.5, 29.4, 29.4, 29.3, 29.2, 29.1, 28.8, 28.6, 26.0; **HR/ESI-Mass** m/z (CH_3CN): $[C_{25}H_{38}O_3S+H]^+$: calc.: 419.2614 $[M+H]^+$, exper. 419.2620.



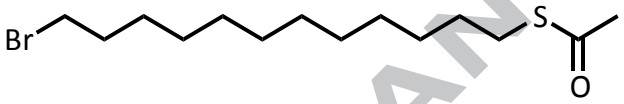
11-acetylthioundecanoic acid (20) was synthesized according to publised procedures.[2]
11-bromoundecanoic acid (2.00 g, 7.54 mmol) was stirred for 18 h at 85 °C in CH_3CN with potassium thioacetate (947 mg, 8.29 mmol). The reaction was quenched with water 850 mL and the product extracted with diethylether (5 x 75 mL). The organic phase was dried over $MgSO_4$, filtered off and concentrated under reduced pressure. The product was obtained after column chromatography (silica, hexane/ethyl acetate (1:1), R_f=0.26) (yield: 1.86 g, 95%).
^{1}H-NMR (400 MHz, $CDCl_3$, 298 K): δ_H (ppm): 2.79 (t, 2H, $^3J_{HH}$ = 7.3 Hz, CH_2S), 2.26 (t+s, 5H, CH_3, CH_2-COOH), 1.54 (m, 4H, CH_2), 1.24 (m, 12H) (cf. Lit.[3]); **^{13}C-NMR** (101 MHz, $CDCl_3$, 298 K): δ_C (ppm): 196.1 ($C_{thioacetate}$), 179.39 ($C_{quart./carbonyl}$), 34.0, 30.6, 29.4, 29.3, 29.2, 29.1, 29.1, 29.0, 29.0, 28.7, 24.6.



4-(4-aminophenyl)-2-methylbut-3-yn-2-ol (21) was obtained from **12** (500 mg, 1.81 mmol) by an acidic deprotection with TBAF (tetra-*n*-butylammonium fluoride) (2.37 g, 9.05 mmol) in THF (35 mL) at 75 °C for 12 h. The reaction mixture was allowed to cool down and was extracted with DCM (3 x 25 mL), washed with water

and brine (each 3 x 25 mL), dried over $MgSO_4$, filtered off and dried under vacuum. The crude was purified by column chromatography (silica, hexane/ethyl acetate (1:1), R_f=0.32) (yield: 289 mg, 90%, yellowish solid).

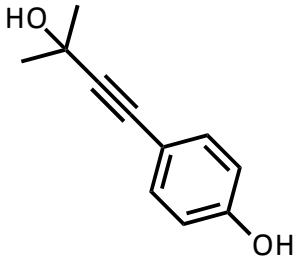
IR (KBr pellet): $_{max}$ (cm^{-1}): 3378 (O-H stretch, N-H stretch), 3035 (C-H stretch, aromatic), 2980 (C-H stretch, alkyl), 2932 (C-H stretch, alkyl), 2980 (C-H stretch, alkyl), 2222 (C≡C stretch), 1621 (N-H stretch, amine), 1608 (N-H stretch, amine), 1513 (C-C stretch, aromatic), 1376 (C-H, alkyl), 1363 (C-H, alkyl), 1280, 1171 (C-O stretch, tertiary alcohol) (cf. Lit.[12]); **^{1}H-NMR** (400 MHz, $CDCl_3$, 298 K): δ_H (ppm): 7.24-7.19 (m, 2H, $H_{arom.}$), 6.61-6.56 (m, 2H, $H_{arom.}$), 3.78 (s, broad, NH_2), 1.59 (s, 6H) (cf. Lit.[12]); **^{13}C-NMR** (101 MHz, $CDCl_3$, 298 K): δ_C (ppm): 146.7 ($C_{quart.}$), 133.1, 114.8, 112.2 ($C_{quart.}$), 91.7 (C_{alkyne}), 82.7 (C_{alkyne}), 65.8 ($C_{quart.}$/$_{t\text{-}Bu}$), 31.8 (CH_3) (cf. Lit.[12]); **UV/VIS** ($CHCl_3$): λ_{max} (nm), (log ε_λ ($M^{-1}cm^{-1}$)): 241, (3.90), 252 (3.00).



***S*-(12-bromododecyl) thioacetate (22)**

A mixture of 1,12-dibromododecane (5.00 g, 15.24 mmol) and potassium thioacetate (1.74 g, 15.24 mmol) was stirred in freshly distilled THF (100 mL) for 6 h at room temperature. The crude product was extracted with diethylether (5 x 70 mL) and washed with water and brine (3 x 50 mL). The combined organic phase was dried over $MgSO_4$, filtered off and concentrated under reduced pressure. The product was obtained as a white solid after column chromatography (silica, gradient: hexane; hexane/ethyl acetate 30:1, hexane/ethyl acetate 10:1, R_f (hexane/ethyl acetate 10:1)=0.6) (yield: 2.07 g, 42%).

^{1}H-NMR (400 MHz, $CDCl_3$, 298 K): δ_H (ppm): 3.38 (t, 2H, $^3J_{HH}$ = 6.9Hz, C*H*$_2$Br), 2.83 (t, 2H, $^3J_{HH}$=7.4 Hz, C*H*$_2$S), 2.23 (s, 3H, CH_3CO), 1.82 (dt, 2H, $^2J_{HH}$=14.7 Hz, $^3J_{HH}$=6.9 Hz, S-CH_2-C*H*$_2$), 1.54 (m, 2H, Br-CH_2-C*H*$_2$), 1.31 (m, 16H, CH_2) (cf. Lit.[1]); **^{13}C-NMR** (101 MHz, $CDCl_3$, 298 K): δ_C (ppm): 195.9 ($C_{thioacetate}$), 34.0, 32.8, 30.6, 29.5, 29.5, 29.4, 29.4, 29.4, 29.1, 29.1, 29.1, 28.8, 28.7, 28.1.

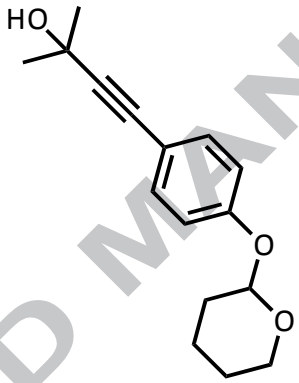


4-(3-hydroxy-3-methylbut-1-yn-1-yl)phenol (23)

2-methyl-4-(4-((tetrahydro-2*H*-pyran-2-yl)oxy)phenyl)but-3-yn-2-ol **(24)** (960 mg, 3.68 mmol) was stirred for 4 h at room temperature with *p*-TsOH (175 mg, 921 µmol) in THF/MeOH (25 mL) (1:2). The crude product was extracted with DCM (3 x 30 mL),

washed with water and brine (each 3 x 30 mL), dried over $MgSO_4$, filtered off, and concentrated under reduced pressure. The product was purified by column chromatography (silica, hexane/ethyl acetate (4:1), R_f=0.2) (yield: 584 mg, 90%, yellow solid).

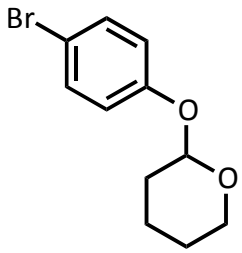
IR (KBr pellet): $_{max}$ (cm^{-1}): 3359 (O-H stretch), 3279 (C-H stretch, aromatic), 3085 (C-H stretch, aromatic), 2981 (C-H stretch, alkyl), 2942 (C-H stretch, alkyl), 2870 (C-H stretch, alkyl), 1201 (C-O stretch); **^{1}H-NMR** (400 MHz, $CDCl_3$, 298 K): δ_H (ppm): 7.30 (d, 2H, $^{3}J_{HH}$ = 8.8 Hz, $H_{arom.}$), 6.78 (d, 2H, $^{3}J_{HH}$ = 8.8 Hz $H_{arom.}$), 1.55 (s, 6H, CH_3/$_{t\text{-Bu}}$) (cf. Lit.[7]) (methanol impurity 3.49); **^{13}C-NMR** (101 MHz, $CDCl_3$, 298 K): δ_C (ppm): 155.9 ($C_{quart.}$), 133.3, 115.4, 114.5 ($C_{quart.}$), 88.9 (C_{alkyne}), 84.4 (C_{alkyne}), 71.5 ($C_{quart.}$/$_{t\text{-Bu}}$), 28.4 (CH_3) (methanol impurity 50.4).



2-methyl-4-(4-((tetrahydro-2*H*-pyran-2-yl)oxy)phenyl)but-3-yn-2-ol (24)

2-methylbut-3-yn-2-ol (982 mg, 11.7 mmol), 5 mL NEt_3 and 20 mL THF were added to a mixture of 2-(4-bromophenoxy)tetrahydro-2*H*-pyran **(25)** (1.00 g, 3.89 mmol), CuI (44 mg, 233 µmol), PPh_3 (61 mg, 233 µmol), and $PdCl_2(PPh_3)_2$ (82 mg, 117 µmol) under nitrogen. The reaction was heated to 80 °C and stirred for 12 h. The reaction was quenched with water (50 mL) and extracted with DCM (3 x 50 mL). The combined organic phase was dried over $MgSO_2$, filtered off, and concentrated under reduced pressure. **24** was obtained as a light yellow solid by column chromatography (silica, hexane/ethyl acetate (4:1), R_f=0.28) (yield: 962 mg, 95%).

IR (KBr pellet): $_{max}$ (cm^{-1}): 3299 (O-H stretch), 3279 (C-H stretch, aromatic), 3085 (C-H stretch, aromatic), 2981 (C-H stretch, alkyl), 2942 (C-H stretch, alkyl), 2870 (C-H stretch, alkyl), 1228 (C-O-C stretch, ether), 1201 (C-O stretch), 1157 (C-O-C stretch, ether), 1056 (C-O-C stretch, ether); **^{1}H-NMR** (400 MHz, $CDCl_3$, 298 K): δ_H (ppm): 7.33 (d, 2H, $^{3}J_{HH}$ = 8.9 Hz, $H_{arom.}$), 6.97 (d, 2H, $^{3}J_{HH}$ = 8.9 Hz, $H_{arom.}$), 5.41 (t, 1H, $^{4}J_{HH}$= 3.3 Hz, OC*H*), 4.12 (m, 1H, OCH_2CH_2), 3.87 (ddd, 1H, $^{2}J_{HH}$ = 11.3, $^{3}J_{HH}$= 9.6, $^{4}J_{HH}$= 3.1 Hz, OCH_2CH_2), 3.61 (m, 1H), 2.00 (m, 2H), 1.85 (m, 1H), 1.67 (m, 2H), 1.60 (s, 6H, C(CH_3)OH), 1.26 (t, 1H, $^{3}J_{HH}$=7.1 Hz) (cf. Lit.[6]); **^{13}C-NMR** (101 MHz, $CDCl_3$, 298 K): δ_C (ppm): 157.0 ($C_{quart.}$), 132.9, 116.3, 115.6 ($C_{quart.}$), 96.2 (O*C*H), 92.41 (C_{alkyne}), 82.0 (C_{alkyne}), 65.6 ($C_{quart./t\text{-Bu}}$), 62.0 (O*C*H2), 31.6, 30.2, 25.1, 18.7.



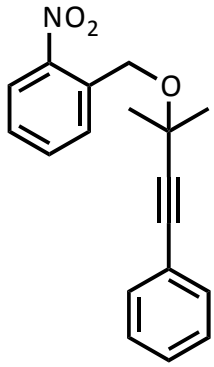
2-(4-bromophenoxy)tetrahydro-2*H*-pyran (25) was synthesized following a known procedure.[4]

4-bromophenol (5.00 g, 28.9 mmol) and 3,4-dihydro-2*H*-pyran (4.86 g, 57.8 mmol) in DCM (50 mL) were stirred for 12 h at room temperature with catalytic amounts of *p*-TsOH (20 mg, 116 µmol). The reaction was quenched with water, the product extracted with DCM (3 x 100 mL), dried over $MgSO_4$, filtered off, and concentrated under reduced pressure. The product was purified by column chromatography (silica, gradient hexane/ethyl acetate (30:1), (10:1), R_f (hexane/ethyl acetate 10:1)=0.1) (yield: 7.06 g, 95%).

IR (KBr pellet): $_{max}$ (cm^{-1}): 3082, 2950 (C-H stretch, alkyl), 2870 (C-H stretch, alkyl), 2710 (C-H stretch, alkyl), 2035, 1879, 1755, 1585 (C-C stretch, aromatic), 1579, 1490 (C-H, alkyl), 1450 (C-H, alkyl), 1437 (C-H, alkyl), 1391 (C-H, alkyl), 1353, 1326, 1280, 1237 (C-O-C stretch, ether), 1160 (C-O-C stretch, ether), 1072, 1056 (C-O-C stretch, ether) (cf. Lit.[5]); **^{1}H-NMR** (400 MHz, $CDCl_3$, 298 K): δ_H (ppm): 7.37 (d, 2H, $^{3}J_{HH}$ = 9.0 Hz, $H_{arom.}$), 6.94 (d, 2H, $^{3}J_{HH}$ = 9.0 Hz, $H_{arom.}$), 5.37 (s, 1H, OC*H*), 3.86 (ddd, 1H, $^{2}J_{HH}$=11.4 Hz, $^{3}J_{HH}$= 9.6 Hz, $^{3}J_{HH}$= 3.2 Hz, OCH_2CH$_2$), 3.59 (dtd, 1H, $^{2}J_{HH}$ = 11.3, $^{3}J_{HH}$= 4.1, $^{4}J_{HH}$= 1.5 Hz, OCH_2CH$_2$), 1.89 (m, 1H), 1.85 (m, 2H), 1.62 (m, 3H) (cf. Lit.[5]); **^{13}C-NMR** (101 MHz, $CDCl_3$, 298 K): δ_C (ppm): 156.1 ($C_{quart.}$), 132.2, 118.3, 113.8 ($C_{quart.}$), 96.4 (O*C*H), 62.0 (O*C*H2), 30.2, 25.1, 18.6 (cf. Lit.[5]).

SI-2 Synthesis and Characterization of the Photo-Cleavable Alkyne Compounds (1-7)

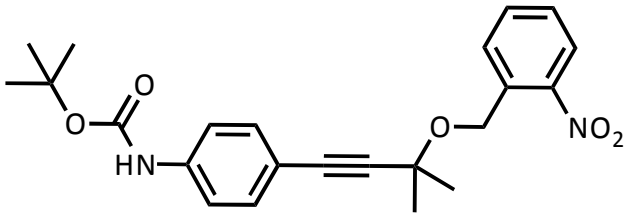
General procedure to build up different photo-cleavable molecules via a mild Cu(II) catalyzed S_{N1} reaction between different propargylic alcohols and 2-nitrobenzyl alcohol.



As an example the synthesis of **1-(((2-methyl-4-phenylbut-3-yn-2-yl)oxy)methyl)-2-nitrobenzene (1)** is described below:

2-nitrobenzyl alcohol (1.00 g, 6.53 mmol), 2-methyl-4-phenylbut-3-yn-2-ol (**8**) (348 mg, 2.18 mmol) and $CuBr_2$ (24 mg, 1.09 mmol) in nitromethane (20 mL) were stirred at room temperature for 12 h in the dark. The crude product was extracted with DCM (3 x 30 mL), the combined organic phase was washed with water and brine (each 3 x 30 mL), dried over $MgSO_4$, filtered off and concentrated under reduced pressure. **1** was obtained after column chromatography (silica, hexane/ethyl acetate (4:1), R_f=0.4) as a yellowish oil (yield: 451 mg, 70%).

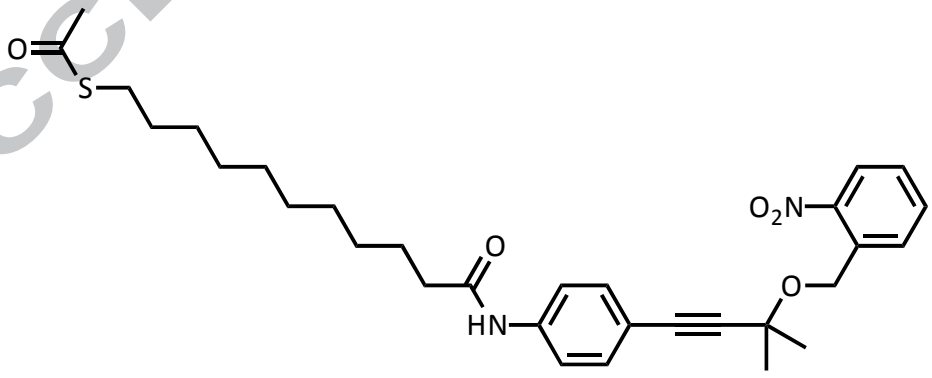
IR (KBr pellet): $_{max}$ (cm^{-1}): 3082 (C-H stretch, aromatic), 3063 (C-H stretch, aromatic), 2984 (C-H stretch, alkyl), 2934 (C-H stretch, alkyl), 2860 (C-H stretch, alkyl), 2230 (C≡C stretch), 1672, 1611, 1598 (C-C stretch, aromatic), 1577 (C-C stretch, aromatic), 1523 (N-O stretch, nitro), 1490 (C-C stretch, aromatic), 1443 (C-C stretch, aromatic), 1379 (C-H, alkyl), 1342 (N-O, nitro), 1284 (C-O-C stretch, ether), 1155 (C-O-C stretch, ether), 1065 (C-O-C stretch, ether; **UV/VIS** ($CHCl_3$): λ_{max} (nm), (log ε_λ ($M^{-1}cm^{-1}$)): 241, (4.53); 252, (4.00); **^{1}H-NMR** (500 MHz, $CDCl_3$, 298 K): δ_H (ppm): 8.05 (dd, 1H, $^3J_{HH}$ = 8.2 Hz, $^4J_{HH}$=1.3 Hz, $H_{arom.}$), 7.90 (dd, 1H, $^3J_{HH}$ = 8.2, 1.3 Hz $H_{arom.}$), 7.64 (td, 1H, $^3J_{HH}$ = 7.6, 1.3 Hz, $H_{arom.}$), 7.45-7.39 (m, 1H, $H_{arom.}$), 7.39-7.34 (m, 1H, $H_{arom.}$), 7.28 (dd, 4H, J_{HH} = 5.2 Hz, J_{HH} 2.1 Hz, $H_{arom.}$), 5.11 (s, 2H), 1.67 (s, 6H, CH_3); **^{13}C-NMR** (125 MHz, $CDCl_3$, 298 K): δ_C (ppm): 147.4 ($C_{quart.}$), 136.1 ($C_{quart.}$), 133.6, 131.8, 129.3, 128.4, 128.4, 127.8, 124.6, 122.7 ($C_{quart.}$), 90.9 (C_{alkyne}), 85.0 (C_{alkyne}), 71.6 ($C_{quart./t\text{-}Bu}$), 63.3 (CH_2), 29.1 (CH_3); **HR/ESI-Mass** m/z (MeOH): $[C_{18}H_{17}NO_3+Na]^+$: calc.: 318.1101, $[M+Na]^+$, exper. 318.1006.



***tert*-butyl (4-(3-methyl-3-((2-nitrobenzyl)oxy)but-1-yn-1-yl)phenyl)carbamate 5** was synthesized according to the general procedure with *tert*-butyl (4-(3-hydroxy-3-methylbut-1-yn-1-yl)phenyl)carbamate **(12)** (500 mg, 1.82 mmol) and 2-nitrobenzyl alcohol (556 mg, 3.63 mmol).

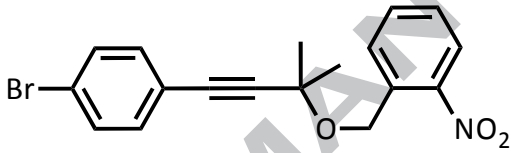
The product was obtained as a yellowish oil after column chromatography (silica, hexane/ethyl acetate (4:1), R_f=0.22) (yield: 426 mg, 57%).

IR (KBr pellet): $_{max}$ (cm^{-1}): 3331 (N-H stretch, amide), 3173 (C-H stretch, aromatic), 3089 (C-H stretch, aromatic), 2981 (C-H stretch, alkyl), 2934 (C-H stretch, alkyl), 2220 (C≡C stretch), 1731 (C=O stretch, carbonyl), 1709 (C=O stretch, carbonyl amide), 1609, 1585 (C-C stretch, aromatic), 1523 (N-O stretch, nitro), 1407, 1392 (C-H, alkyl), 1367 (C-H, alkyl), 1341 (N-O, nitro), 1230 (C-O-C stretch, ether), 1157 (C-O-C stretch, ether), 1056 (C-O-C stretch, ether); **UV/VIS** ($CHCl_3$): λ_{max} (nm), (log ε_λ ($M^{-1}cm^{-1}$)): 268, (4.60); **^{1}H-NMR** (400 MHz, $CDCl_3$, 298 K): δ_H (ppm): 8.02 (dd, 1H, $^3J_{HH}$ = 8.2, 1.3 Hz, $H_{arom.}$), 7.88 (dd, 1H, $^3J_{HH}$ = 8.2, 1.3 Hz $H_{arom.}$), 7.61 (td, 1H, $^3J_{HH}$ = 7.7, 1.3 Hz, $H_{arom.}$), 7.38 (td, 1H, $^3J_{HH}$ = 7.7, 1.3 Hz, $H_{arom.}$), 7.26 (dd, 4H, $^3J_{HH}$ = 7.6, 1.3 Hz, $H_{arom.}$), 6.56 (s, broad, 1H, NH), 5.07 (s, 2H), 1.63 (s, 6H, CH_3), 1.49 (s, 9H, CH_3/$_{t\text{-Bu}}$); **^{13}C-NMR** (101 MHz, $CDCl_3$, 298 K): δ_C (ppm): 152.5 ($C_{quart./carbonyl}$), 147.4 ($C_{quart.}$), 138.6 ($C_{quart.}$), 136.1 ($C_{quart.}$), 133.6, 132.6, 129.3, 127.7, 124.5, 118.0, 116.9 ($C_{quart.}$), 89.9 (C_{alkyne}), 84.8 (C_{alkyne}), 81.0 ($C_{quart.}$ /$_{t\text{-Bu}}$), 71.6 ($C_{quart.}$/$_{t\text{-Bu}}$), 63.3 (CH_2), 29.1 (CH_3), 28.4 (CH_3/$_{t\text{-Bu}}$); **HR/ESI-Mass** m/z (MeOH): $[C_{23}H_{26}N_2O_5+H]^+$: calc.: 433.1734 $[M+Na]^+$, exper. 433.1739 $[M+Na]^+$.



***S*-(11-((4-(3-methyl-3-((2-nitrobenzyl)oxy)but-1-yn-1-yl)phenyl)amino)-11-oxoundecyl) ethanethioate 6** was synthesized according to the procedure given for **1** with *S*-(11-((4-(3-methyl-3-((2-nitrobenzyl)oxy)but-1-yn-1-yl)phenyl)amino)-11-oxoundecyl) ethanethioate (**13**) (100 mg, 242 µmol) and 2-nitrobenzyl alcohol (74 mg, 485 µmol). The product was obtained as a yellowish oil after column chromatography (silica, hexane/ethyl acetate (1:1), R_f=0.4) (yield: 56 mg, 42%).

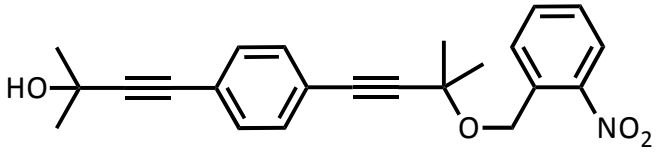
IR (KBr pellet): $_{max}$ (cm^{-1}): 3311 (N-H stretch, amide), 3181 (C-H stretch, aromatic), 3100 (C-H stretch, aromatic), 2983 (C-H stretch, alkyl), 2927 (C-H stretch, alkyl), 2854 (C-H stretch, alkyl), 2218 (C≡C stretch), 1691 (S-C=O stretch, amine), 1666 (C=O stretch, amide), 1592 (C-C stretch, aromatic), 1525 (N-O stretch, nitro), 1465 (C-C stretch, aromatic), 1341 (N-O, nitro), 1248 (S-C stretch), 1141; **UV/VIS** ($CHCl_3$): λ_{max} (nm), (log ε_λ ($M^{-1}cm^{-1}$)): 273, (4.57); 286, (4.20); **^{1}H-NMR** (400 MHz, $CDCl_3$, 298 K): δ_H (ppm): 8.01 (dd, 1H, $^3J_{HH}$ = 8.2, 1.4 Hz, $H_{arom.}$), 7.87 (dd, 1H, $^3J_{HH}$ = 8.2, 1.4 Hz $H_{arom.}$), 7.61 (td, 1H, $^3J_{HH}$ = 7.6 Hz, $^4J_{HH}$ =1.3 Hz, $H_{arom.}$), 7.47 (m, 2H, $H_{arom.}$), 7.38 (m, 1 H, $H_{arom.}$), 7.27 (m, 2H), 5.06 (s, 2H), 2.83 (m, 2H), 2.31 (d, 5H, $^3J_{HH}$ = 5.6 Hz), 1.95 (s, broad, 1H, NH), 1.63 (s, 8H, CH_3), 1.52 (m, 2H), 1.27 (m, 12H); **^{13}C-NMR** (101 MHz, $CDCl_3$, 298 K): δ_C (ppm): 196.4 ($C_{quart./SCO}$), 171.7 ($C_{quart./carbonyl}$), 147.2 ($C_{quart.}$), 138.2 ($C_{quart.}$), 135.9 ($C_{quart.}$), 133.5,132.4, 129.1, 127.6, 124.4, 119.2, 117.8 ($C_{quart.}$), 90.1 ($C_{quart./alkyne}$), 84.6 ($C_{quart./alkyne}$), 71.5 ($C_{quart./t\text{-}Bu}$), 63.1 (CH_2), 37.7, 30.7, 29.4, 29.3, 29.3, 29.2, 29.2, 29.2, 29.1, 29.1, 29.0, 28.9, 28.8, 28.7, 25.5, 23.5; **HR/ESI-Mass** m/z (MeOH): $[C_{31}H_{40}N_2O_5S+Na]^+$: calc.: 575.2550 $[M+Na]^+$, exper. 575.2556.



1-(((4-(4-bromophenyl)-2-methylbut-3-yn-2-yl)oxy)methyl)-2-nitrobenzene (2)

2 was synthesized according to the procedure described for compound **1** with 4-(4-bromophenyl)-2-methylbut-3-yn-2-ol **(9)** (260.1 mg, 1.09 mmol) and 2-nitrobenzyl alcohol (334 mg, 2.18 mmol). The product was obtained as a yellowish oil after column chromatography (silica, hexane/ethyl acetate (4:1), R_f=0.4) (yield: 297 mg, 73%).

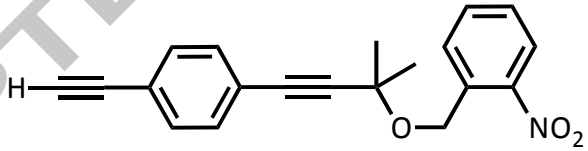
IR (KBr pellet): $_{max}$ (cm^{-1}): 3085 (C-H stretch, aromatic), 3068 (C-H stretch, aromatic), 2984 (C-H stretch, alkyl), 2933 (C-H stretch, alkyl), 2857 (C-H stretch, alkyl), 2234 (C≡C stretch), 1611, 1578 (C-C stretch, aromatic), 1524 (N-O stretch, nitro), 1487 (C-C stretch, aromatic), 1393 (C-H, alkyl), 1379 (C-H, alkyl), 1341 (N-O, nitro), 1280 (C-O-C stretch, ether), 1155 (C-O-C stretch, ether), 1069 (C-O-C stretch, ether); **UV/VIS** ($CHCl_3$): λ_{max} (nm), (log ε_λ ($M^{-1}cm^{-1}$)): 261, (4.46); 252, (4.05); **^{1}H-NMR** (400 MHz, $CDCl_3$, 298 K): δ_H (ppm): 8.04 (dd, 1H, $^3J_{HH}$ = 8.3, 1.3 Hz, $H_{arom.}$), 7.89 (dd, 1H, $^3J_{HH}$ = 8.3, 1.3 Hz $H_{arom.}$), 7.64 (td, 1H, $^3J_{HH}$ = 15.3, 1.3 Hz, $H_{arom.}$), 7.40 (m, 3H, $H_{arom.}$), 7.22 (d, 2H, $^3J_{HH}$ = 8.6 Hz, $H_{arom.}$), 5.09 (s, 2H), 1.66 (s, 6H, CH_3); **^{13}C-NMR** (101 MHz, $CDCl_3$, 298 K): δ_C (ppm): 147.3 ($C_{quart.}$), 135.8 ($C_{quart.}$), 133.5, 133.1, 131.5, 129.1, 127.7, 124.4, 122.6 ($C_{quart.}$), 121.5 ($C_{quart.}$), 91.9 (C_{alkyne}), 83.8 (C_{alkyne}), 71.4 ($C_{quart./t\text{-}Bu}$), 63.2 (CH_2), 28.8 (CH_3); **HR/ESI-Mass** m/z (MeOH): $[C_{18}H_{16}BrNO_3+Na]^+$: calc.: 396.0206 $[M+Na]^+$, exper. 396.0211.



2-methyl-4-(4-(3-methyl-3-((2-nitrobenzyl)oxy)but-1-yn-1-yl)phenyl)but-3-yn-2-ol (3)

NEt_3 (3 mL) and THF (7 mL) were added to a mixture of 1-(((4-(4-bromophenyl)-2-methylbut-3-yn-2-yl)oxy)methyl)-2-nitrobenzene **(2)** (90 mg, 240 µmol), CuI (2.73 mg, 240 µmol), PPh_3 (3.78 mg, 144 µmol), and $PdCl_2(PPh_3)_2$ (5.1 mg, 7.2 µg), 2-methylbut-3-yn-2-ol (60 mg, 721 µmol) under nitrogen. The reaction mixture was heated to 80 °C for 12 h. The reaction was quenched with water (25 mL), and extracted with DCM (3 x 25 mL). The combined organic phase was dried over $MgSO_2$, filtered off, and concentrated under reduced pressure. The product was obtained as an yellow oil by column chromatography (silica, hexane/ethyl acetate (4:1), R_f=0.14) (yield: 86 mg, 95%).

IR (KBr pellet): ν_{max} (cm^{-1}): 3401 (O-H stretch; N-H stretch, amide), 3081 (C-H stretch, aromatic), 3041 (C-H stretch, aromatic), 2983 (C-H stretch, alkyl), 2936 (C-H stretch, alkyl), 2870 (C-H stretch, alkyl), 2229 (C≡C stretch), 1611, 1577 (C-C stretch, aromatic), 1525 (N-O stretch, nitro), 1378 (C-H, alkyl), 1361 (C-H, alkyl), 1342 (N-O, nitro), 1275 (C-O-C stretch, ether), 1155, 1065 (C-O-C stretch, ether); **UV/VIS** ($CHCl_3$): λ_{max} (nm), (log ε_λ ($M^{-1}cm^{-1}$)): 270, (4.56); 281, (4.20); **^{1}H-NMR** (400 MHz, $CDCl_3$, 298 K): δ_H (ppm): 8.03 (dd, 1H, $^3J_{HH}$ = 8.2, 1.3 Hz, $H_{arom.}$), 7.88 (dd, 1H, $^3J_{HH}$ = 8.2, 1.3 Hz $H_{arom.}$), 7.63 (td, 1H, $^3J_{HH}$ = 7.6, 1.3 Hz, $H_{arom.}$), 7.40 (ddd, 1H, $^3J_{HH}$ = 8.7, 7.6, 1.5 Hz $H_{arom.}$), 7.35-7.24 (m, 4 H, $H_{arom.}$), 5.08 (s, 2H), 1.65 (s, 6H, CH_3), 1.60 (s, 6H, CH_3); **^{13}C-NMR** (101 MHz, $CDCl_3$, 298 K): δ_C (ppm): 147.3 ($C_{quart.}$), 135.9 ($C_{quart.}$), 133.6, 131.6, 131.6, 129.2, 127.8, 124.6, 122.8 ($C_{quart.}$), 122.4 ($C_{quart.}$), 95.6 ($C_{quart./alkyne}$), 92.5 ($C_{quart./alkyne}$), 84.5 ($C_{quart./alkyne}$), 81.8 ($C_{quart./alkyne}$), 71.5 ($C_{quart.}$/$_{t\text{-}Bu}$), 65.7 ($C_{quart.}$/$_{t\text{-}Bu}$), 63.3 (CH_2), 31.5 (CH_3), 29.0 (CH_3); **HR/ESI-Mass** m/z (MeOH): $[C_{23}H_{23}NO_4+Na]^+$: calc.: 400.1519 $[M+Na]^+$, exper. 400.1525.

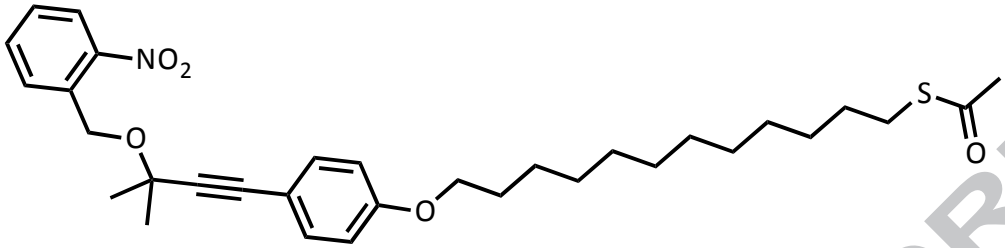


1-(((4-(4-ethynylphenyl)-2-methylbut-3-yn-2-yl)oxy)methyl)-2-nitrobenzene (4)

2-methyl-4-(4-(3-methyl-3-((2-nitrobenzyl)oxy)but-1-yn-1-yl)phenyl)but-3-yn-2-ol **(3)** (30 mg, 80 µmol) was stirred for 16 h with KOH (90 mg, 1.6 mmol) in toluene (5 mL) at 110 °C in the dark. **4** was obtained after column chromatography (silica, hexane/ethyl acetate (4:1), R_f=0.2) (yield: 20 mg, 80%).

IR (KBr pellet): ν_{max} (cm^{-1}): 3291 (C-H stretch, acetylenic), 3059 (C-H stretch, aromatic), 2985 (C-H stretch, alkyl), 2934 (C-H stretch, alkyl), 1611, 1577 (C-C stretch, aromatic), 1524 (N-O stretch, nitro), 1435 (C-C stretch, aromatic), 1380 (C-H, alkyl), 1341 (N-O, nitro), 1280 (C-O-C stretch, ether), 1184 (C-O-C stretch, ether), 1091 (C-O-C stretch, ether), 1064 (C-O-C stretch, ether); **UV/VIS** ($CHCl_3$): λ_{max} (nm), (log ε_λ ($M^{-1}cm^{-1}$)): 267, (4.34); 279 (4.01); **^{1}H-NMR** (400 MHz, $CDCl_3$, 298 K): δ_H (ppm): 8.04 (dd, 1H, $^3J_{HH}$ = 8.3 Hz, $^4J_{HH}$ =1.6 Hz, $H_{arom.}$), 7.88 (d, 1H, $^3J_{HH}$ = 8.3 Hz, $H_{arom.}$), 7.63 (td, 1H, $^3J_{HH}$ = 7.7 Hz, $^4J_{HH}$=1.3 Hz, $H_{arom.}$), 7.36 (m, 5H, $H_{arom.}$), 5.09 (s, 2H), 3.14 (s, 1H, H_{alkyne}), 1.65 (s, 6H, CH_3); **^{13}C-NMR** (101 MHz, $CDCl_3$, 298 K): δ_C (ppm): 147.2 ($C_{quart.}$), 135.8 ($C_{quart.}$), 133.5, 132.0, 131.6, 129.1, 127.7, 124.5, 123.0 ($C_{quart.}$), 122.0 ($C_{quart.}$), 92.7 ($C_{quart./alkyne}$), 84.3 ($C_{quart./alkyne}$), 83.1 ($C_{quart./alkyne}$), 78.8 ($C_{quart./alkyne}$), 71.4 ($C_{quart.}$/$_{t\text{-}Bu}$),

63.2 (CH_2), 28.8 (CH_3); **HR/ESI-Mass** m/z (MeOH): $[C_{20}H_{17}NO_3+Na]^+$: calc.: 342.1101 $[M+Na]^+$, exper. 342.1117.



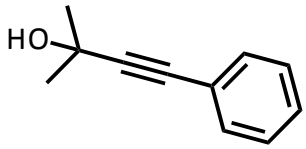
***S*-(12-(4-(3-methyl-3-((2-nitrobenzyl)oxy)but-1-yn-1-yl)phenoxy)dodecyl) ethanethioate (7)**

7 was synthesized according to the procedure described for **1** with *S*-(12-(4-(3-hydroxy-3-methylbut-1-yn-1-yl)phenoxy)dodecyl) ethanethioate **(14)** (250 mg, 598 µmol) and 2-nitrobenzyl alcohol (183 mg, 1.195 mmol). The product was obtained as a yellowish oil after column chromatography (silica, hexane/ethyl acetate (4:1), R_f=0.3) (yield: 159 mg, 48%).

IR (KBr pellet): $_{max}$ (cm^{-1}): 2925 (C-H stretch, alkyl), 2852 (C-H stretch, alkyl), 2218 (C≡C stretch), 1750, 1692 (C=O, thioacetate), 1602 (C-C stretch, aromatic), 1527 (N-O stretch, nitro), 1509, 1463 (C-C stretch, aromatic), 1343 (N-O, nitro), 1284 (C-O-C stretch, ether), 1245 (C-O-C stretch, ether), 1179 (C-O-C stretch, ether), 1134 (C-O-C stretch, ether), 1107 (C-O-C stretch, ether), 1037 (C-O-C stretch, ether); **UV/VIS** ($CHCl_3$): λ_{max} (nm), (log ε_λ ($M^{-1}cm^{-1}$)): 266, (4.33); 277 (4.00); 297 (shoulder); **^{1}H-NMR** (400 MHz, $CDCl_3$, 298 K): δ_H (ppm): 8.04 (dd, 1H, $^3J_{HH}$ = 8.2 Hz, $^4J_{HH}$ = 1.3 Hz, $H_{arom.}$), 7.91 (m, 1H, $H_{arom.}$), 7.52 (td, 1H, $^3J_{HH}$ = 7.6 Hz, $^4J_{HH}$ = 1.3 Hz, 7.42 (m, 1H, $H_{arom.}$), 7.29 (m, 2H), 6.79 (m, 2H, $H_{arom.}$), 5.09 (s, 2H, $H_{benzyl.}$), 3.93 (t, 2H, $^3J_{HH}$= 6.6 Hz, *C*-S-C=O), 2.86 (m, 4H, *C*-S-C=O), 2.32 (s, 3H), 1.74 (m, 4H), 1.65 (s, 6H, $C_{t\text{-}Bu}$), 1.54 (m, 2H, CH_2), 1.32 (m, 12H, CH_2) (methanol impurity 3.49); **^{13}C-NMR** (101 MHz, $CDCl_3$, 298 K): δ_C (ppm): 196.0 ($C_{quart./thioacetate}$), 159.2 ($C_{quart.}$), 147.3 ($C_{quart.}$), 136.1 ($C_{quart.}$), 133.4, 133.1, 132.2129.1, 127.5, 124.4, 114.4, 114.0 ($C_{quart.}$), 89.1 ($C_{quart./alkyne}$), 84.8 ($C_{quart./alkyne}$), 71.5 ($C_{quart./t\text{-}Bu}$), 68.0 ($C_{arom.}$-O-*C*), 63.1 (CH_2), 30.6, 29.5, 29.5, 29.4, 29.3, 29.1, 29.1, 29.0, 28.8, 26.0; **HR/ESI-Mass** m/z (CH_3CN): $[C_{32}H_{43}NO_5S+H]^+$: calc.: 554.2935 $[M+H]^+$, exper. 554.2940.

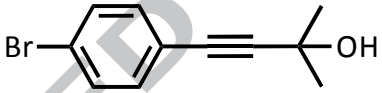
SI-3 Light Irradiation of Compounds 1-7

The light induced deprotection of the photo-caged molecules was done for compounds **1-7**. A general procedure is described for compound **1**:



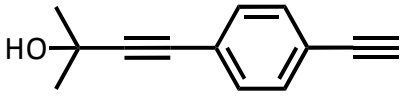
1 (100 mg, 339 µmol) was dissolved in either $CHCl_3$, THF, methanol or DCM (15 mL) and stirred for 120 min irradiated by a UV-lamp (365 nm, 200 µWatt/cm^2) in a distance of around 2 cm. If the reaction is performed in $CDCl_3$, the reaction can be followed by NMR (see Scheme 1). The crude product was extracted with DCM (3 x 30 mL), washed with water (2 x 25 mL), dried over $MgSO_4$, filtered off and concentrated under reduced pressure. The product was obtained after column chromatography (silica, hexane/ethyl acetate (4:1), R_f=0.33). Compound **8** was obtained (characterization see above) (yield: 52 mg, 96%).

The byproduct, 2-nitrosobenzaldehyde (Lit.[15]), can be identified by NMR-spectroscopy.

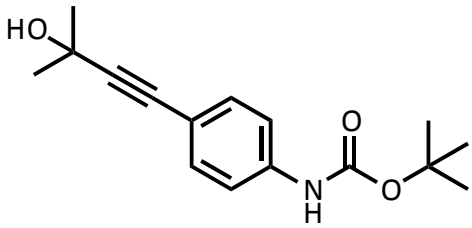


9 was obtained according to the above mentioned procedure starting from **2** (characterization see above) (yield: 60 mg, 94%).

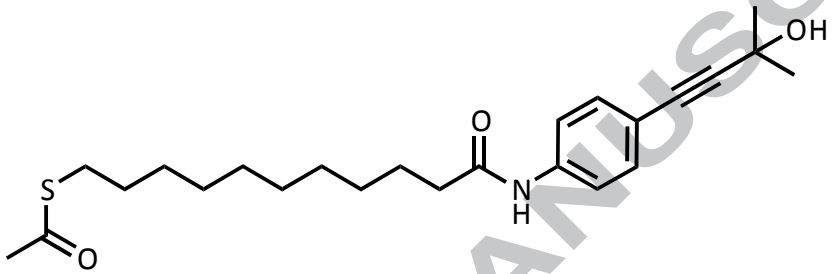
4-4´-(1,4-pheynylene)bis(2-methylbut-3-yn-2-ol) (**10**) was synthesized according to the above mentioned procedure starting from **3** (yield: 55 mg, 86%).
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.35 (m, 4H), 2.04 (s, 2H), 1.60 (s, 12H). **^{13}C NMR** (100.5 MHz, $CDCl_3$) δ 131.9, 122.5, 95.5, 81.6, 65.4, 31.4. Comparable with characterization in Lit.[16,17]



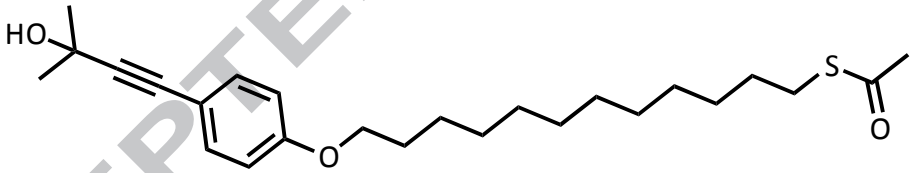
4-(4-ethynylphenyl)-2-methylbut-3-yn-2-ol (**11**) was synthesized according to the above mentioned procedure starting from **4** (yield: 51 mg, 88%).
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.43 (d, *J* = 8.1 Hz, 2H), 7.37 (d, *J* = 8.1 Hz, 2H), 3.16 (s, 1H), 2.02 (s, 1H), 1.63 (s, 6H). **^{13}C NMR** (100.5 MHz, $CDCl_3$) δ 131.9, 131.5, 95.6, 82.7, 81.6, 78.8, 64.8, 31.4. Comparable with characterization in Lit.[18]



12 (***tert*-butyl (4-(3-hydroxy-3-methylbut-1-yn-1-yl)phenyl)carbamate**) was synthesized according to the above mentioned procedure starting from **5** (yield: 60 mg, 90%) (characterization see above).



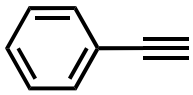
13 (***S*-(11-((4-(3-methyl-3-((2-nitrobenzyl)oxy)but-1-yn-1-yl)phenyl)amino)-11-oxoundecyl) ethanethioate**) was synthesized according to the above mentioned procedure starting from **6** (yield: 70 mg, 92%) (characterization see above).



14 (***S*-(12-(4-(3-hydroxy-3-methylbut-1-yn-1-yl)phenoxy)dodecyl) ethanethioate**) was synthesized according to the above mentioned procedure starting from **7** (yield: 71 mg, 94%) (characterization see above).

SI-4 Alkaline Irradiation of Compounds 1-7

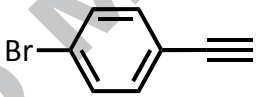
The light-induced reaction under alkaline conditions leads to terminal alkynes. A general procedure is given for compound **1** leading to compound **9** is described here.



ethynylbenzene (15)

1 (100 mg, 624 µmol) was dissolved in toluene (10 mL) under nitrogen conditions. KOH powder (700 mg, 12.5 mmol) was added and the reaction mixture stirred under reflux (110°C)and irradiation with a UV-lamp (365 nm, 200 µWatt/cm^2) for 16 h. The reaction was quenched by the addition of water. The crude product was extracted with DCM (3 x 30 mL), dried over $MgSO_4$, filtered off and concentrated under reduced pressure. The product was purified by flash chromatography to remove the side product 2-nitrosobenzaldehyde. (yield: 45 mg, 70%)

^{1}H-NMR (400 MHz, $CDCl_3$, 298 K): δ_H (ppm): 7.48 (m, 2H, $H_{arom.}$), 7.30 (m, 3H, $H_{arom.}$), 3.07 (s, 1H, H_{alkyne}); **^{13}C-NMR** (101 MHz, $CDCl_3$, 298 K): δ_C (ppm): 132.2, 128.6, 128.1 ($C_{quart.}$), 122.2 ($C_{quart.}$), 83.5 (C_{alkyne}), 77.3 (C_{alkyne}); compound known from Lit.[13,19]



1-bromo-4-ethynylbenzene (16)

2, reaction time: 5 h (yield: 38 mg, 78%)

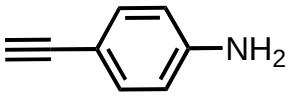
^{1}H-NMR (400 MHz, $CDCl_3$, 298 K): δ_H (ppm): 7.47 (d, 2H, $^3J_{HH}$ = 8.5 Hz, $H_{arom.}$), 7.36 (d, 2H, $^3J_{HH}$ = 8.5 Hz, $H_{arom.}$), 3.14 (s, 1H, H_{alkyne}); **^{13}C-NMR** (101 MHz, $CDCl_3$, 298 K): δ_C (ppm): 134.1, 132.3, 122.9 ($C_{quart.}$), 121.0 ($C_{quart.}$), 83.4 (C_{alkyne}), 77.4 (C_{alkyne}); compound known from Lit.[20,21]

1,4-diethynylbenzene (17)

3, reaction time: 12 h (yield: 23 mg, 70%)

4, reaction time: 12 h (yield: 25 mg, 62%)

^{1}H-NMR (400 MHz, $CDCl_3$, 298 K): δ_H (ppm): 7.43 (s, 4H, $H_{arom.}$), 3.17 (s, 2H, H_{alkyne}); **^{13}C-NMR** (101 MHz, $CDCl_3$, 298 K): δ_C (ppm): 132.7, 123.0 ($C_{quart.}$), 84.0 (C_{alkyne}), 78.4 (C_{alkyne}); compound known from Lit.[16,17]



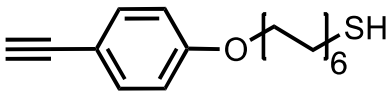
4-ethynylaniline (18)

5, reaction time: 10 h (yield: 14 mg, 50%)

6, reaction time: 12 h (yield: 9 mg, 42%)

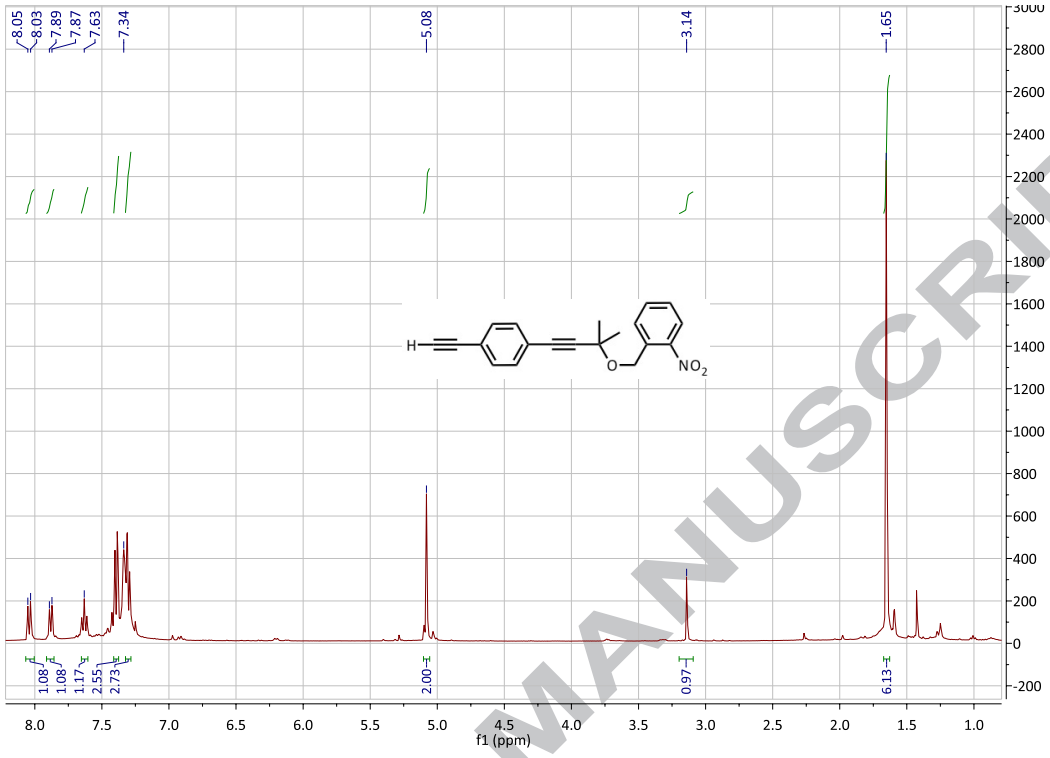
^{1}H-NMR (400 MHz, $CDCl_3$, 298 K): δ_H (ppm): 7.31 (d, 2H, $^3J_{HH}$ = 8.6 Hz, $H_{arom.}$), 6.63 (d, 2H, $^3J_{HH}$ = 8.6 Hz, $H_{arom.}$), 3.82 (s, 2H, NH_2), 2.98 (s, 1H, H_{alkyne}); **^{13}C-NMR** (101 MHz,

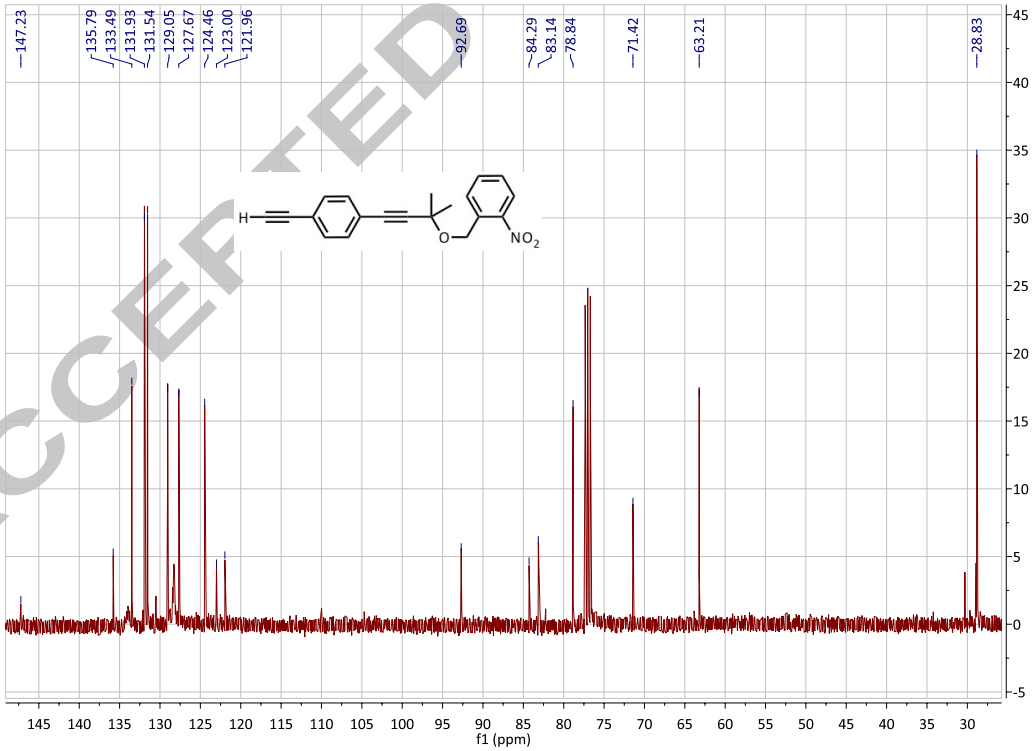
$CDCl_3$, 298 K): δ_C (ppm): 147.1 ($C_{quart.}$), 133.6, 114.6, 111.2 ($C_{quart.}$), 84.4 ($C_{quart./alkyne}$), 75.0 ($C_{quart./alkyne}$); compound known from Lit.[22–24]

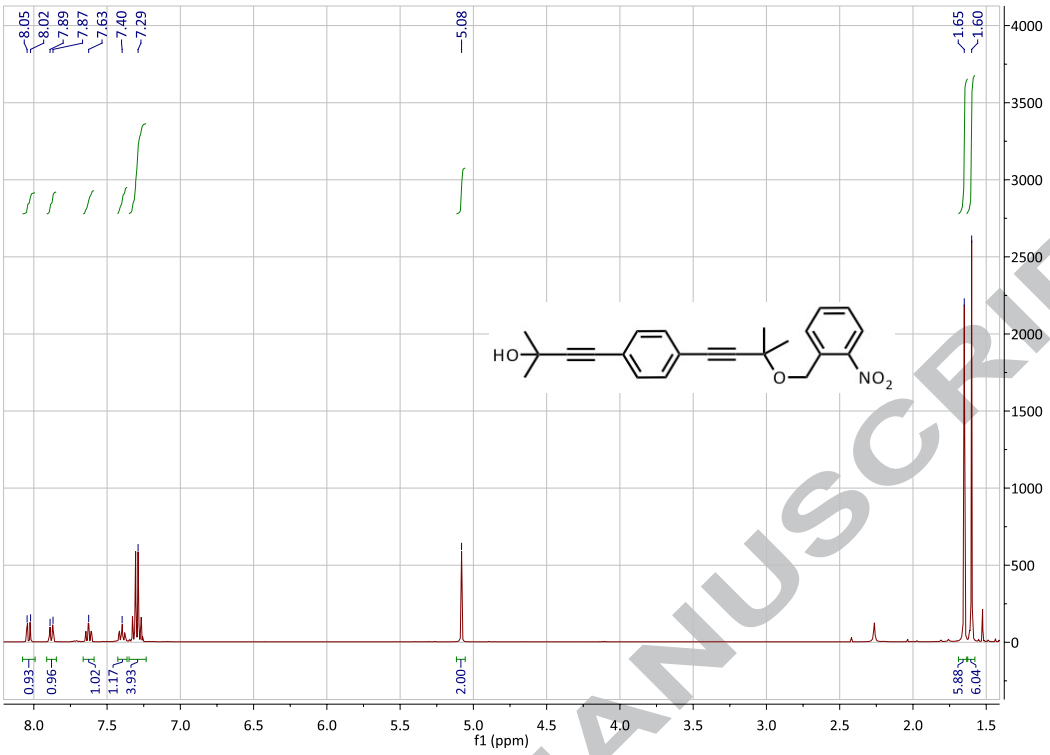


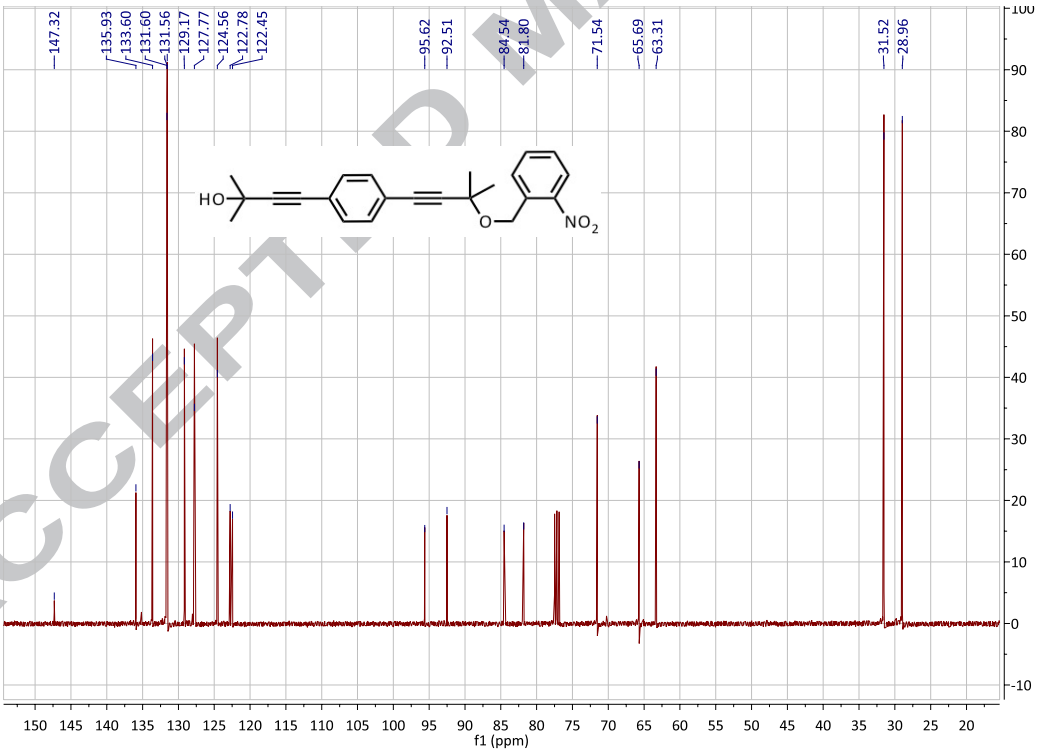
12-(4-ethynylphenoxy)dodecane-1-thiol (19)
7, reaction time: 14 h (yield: 39 mg, 52%)
IR (KBr pellet): $_{max}$ (cm^{-1}): 2925 (C-H stretch, alkyl), 2851 (C-H stretch, alkyl), 2220 (C≡C stretch), 1634, 1606, 1509, 1466, 1376 (C-H, alkyl), 1259 (C-O-C stretch, ether), 1169 (C-O-C stretch, ether), 1169 (C-O-X stretch, ether/alcohol), 1078 (C-O-X stretch, ether/alcohol); **UV/VIS** ($CHCl_3$): λ_{max} (nm), (log ε_λ ($M^{-1}cm^{-1}$)): 254, (4.00); **^{1}H-NMR** (400 MHz, $CDCl_3$, 298 K): δ_H (ppm): 7.33 (d, 2H, $^3J_{HH}$ = 8.9 Hz, $H_{arom.}$), 6.79 (d, 2H, $^3J_{HH}$=8.9 Hz, $H_{arom.}$), 3.92 (t, 2H, $^3J_{HH}$= 6.6 Hz, $C_{arom.}$-O-*C*), 2.49 (m, 3H), 1.74 (m, 1H), 1.58 (m, 2H, CH_2), 1.29 (m, 17H, CH_2) (methanol impurity 3.49); **^{13}C-NMR** (101 MHz, $CDCl_3$, 298 K): δ_C (ppm): 159.1 ($C_{quart.}$), 133.0, 114.6, 114.3 ($C_{quart.}$), 89.3 (C_{alkyne}), 84.2 (C_{alkyne}), 68.0 ($C_{arom.}$-O-*C*), 63.0, 34.0, 32.8, 32.2, 29.7, 29.5, 29.4, 29.2, 29.1, 29.0, 28.4, 28.4, 26.0, 25.7, 24.6 (methanol impurity 50.41); **HR/ESI-Mass** m/z (DMC/MeOH): $[C_{20}H_{30}OS\text{-}H]^+$: calc.: 317.1945 $[M\text{-}H]^+$, exper. 317.1723.

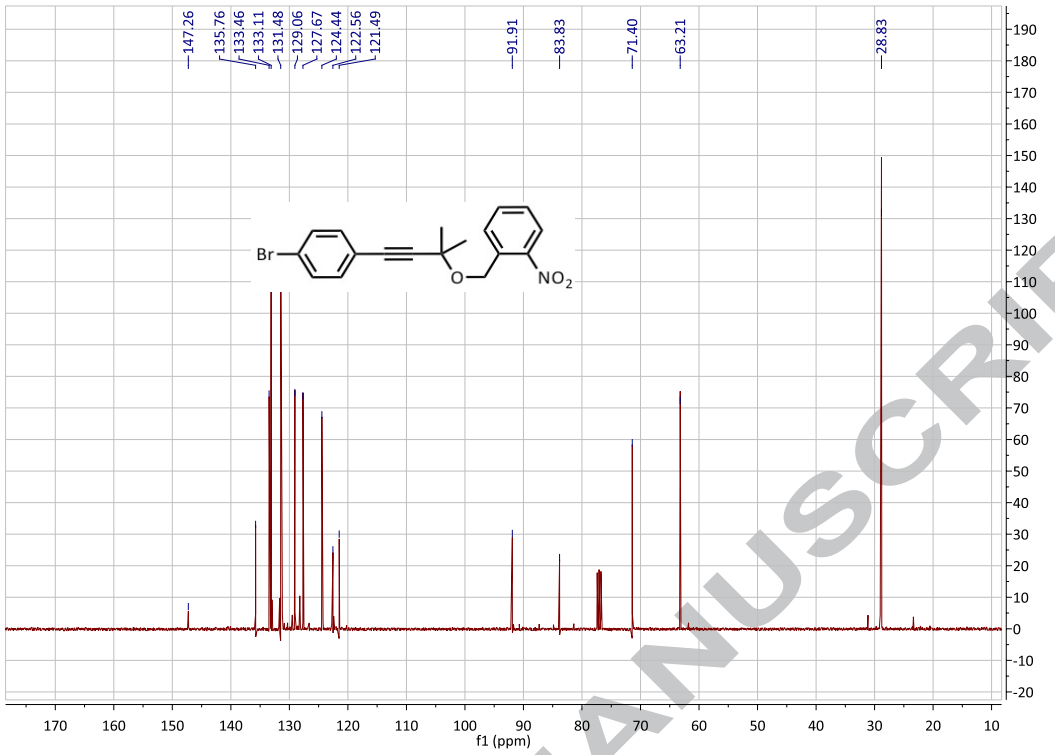
SI-5 NMR:

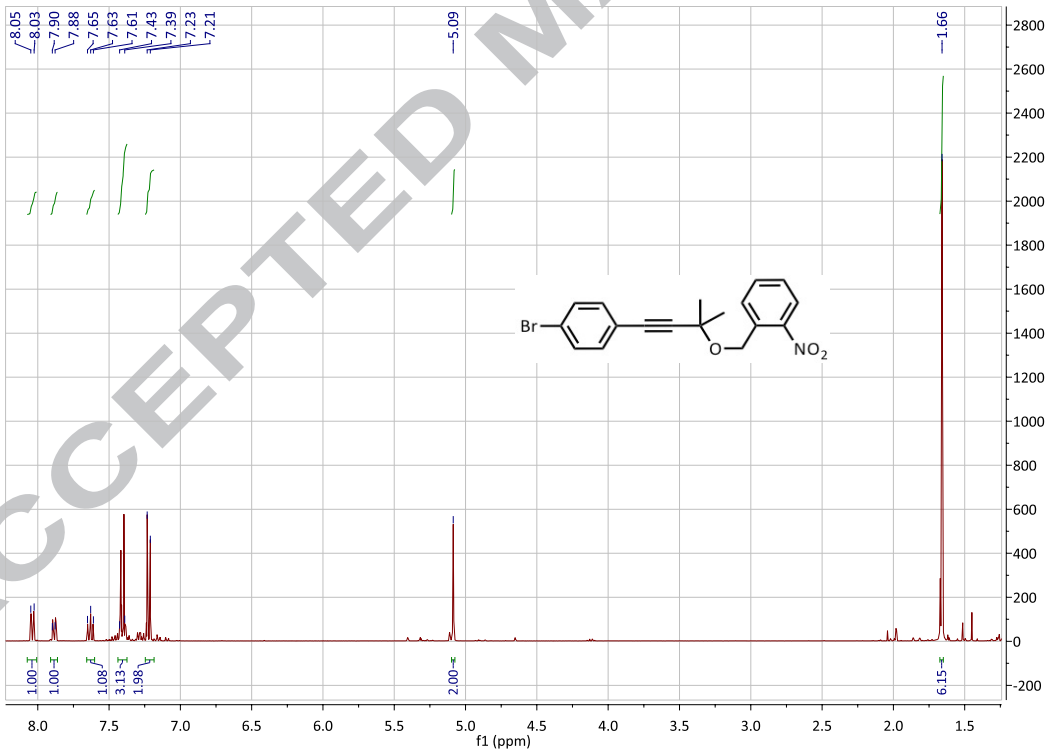


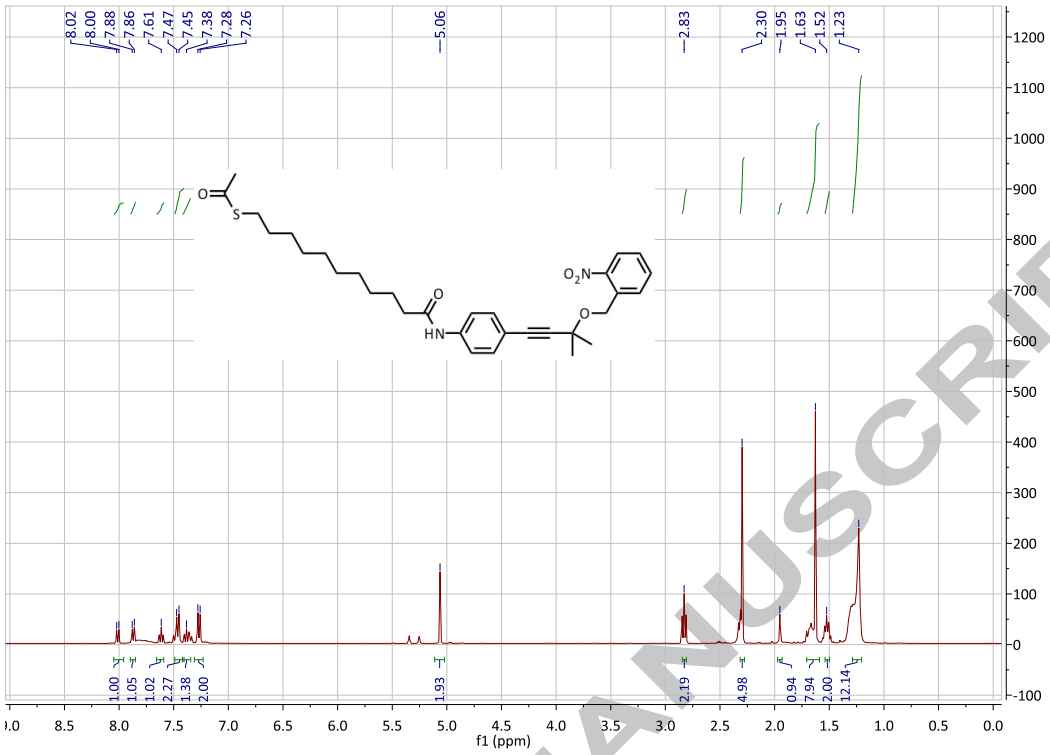


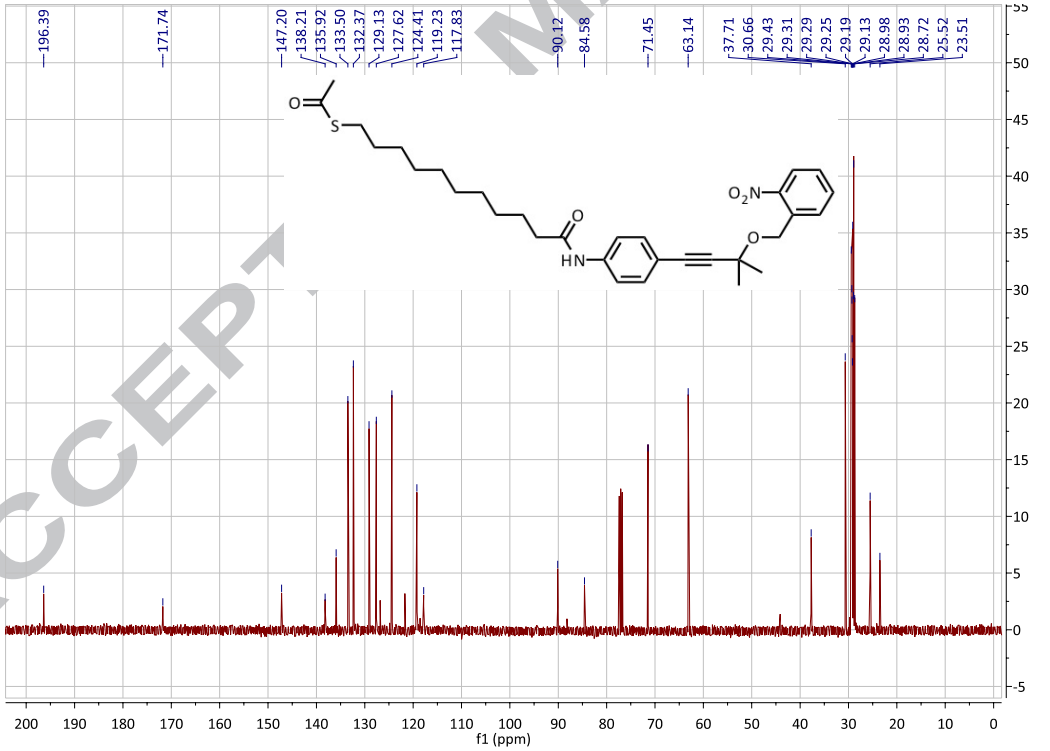


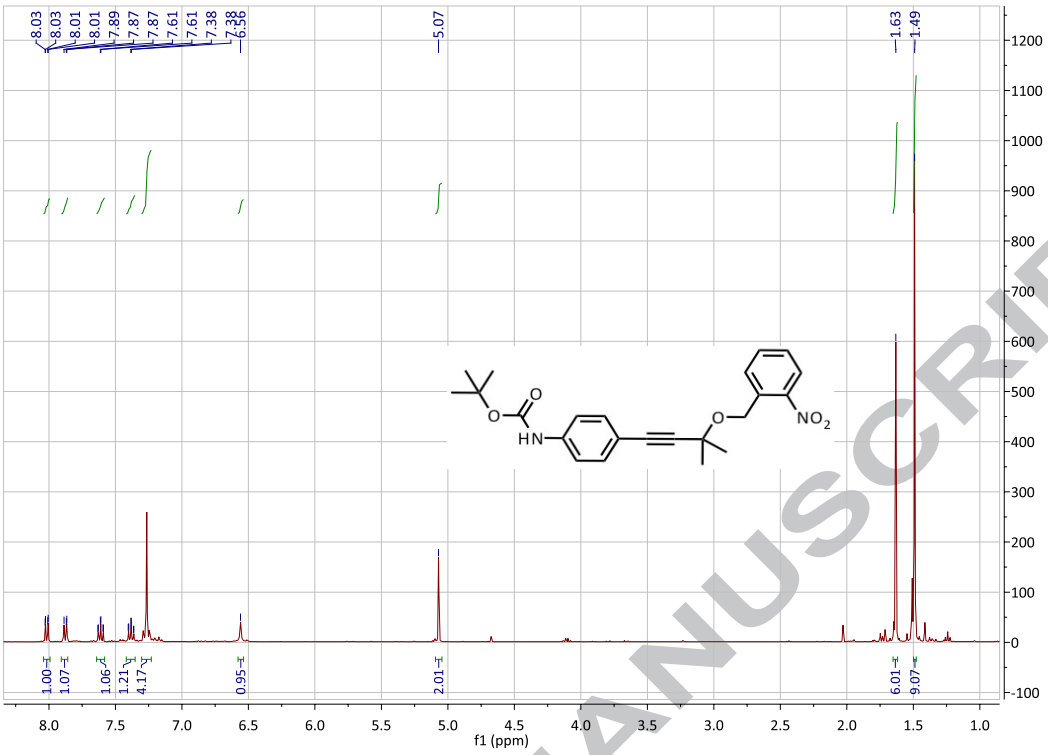


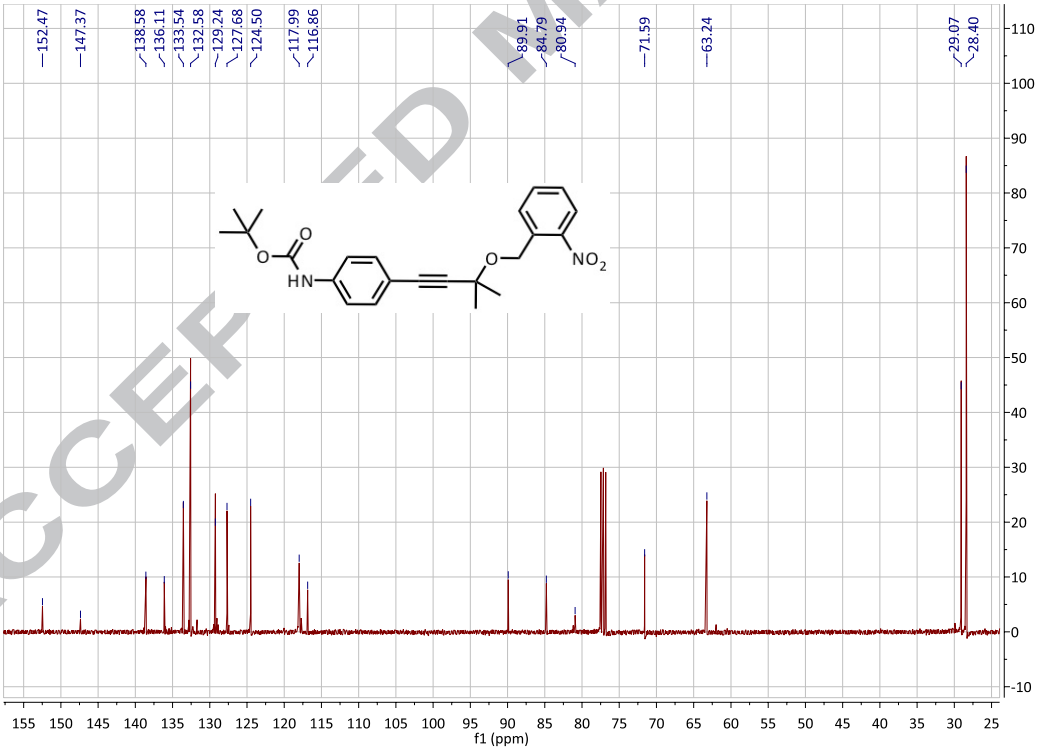


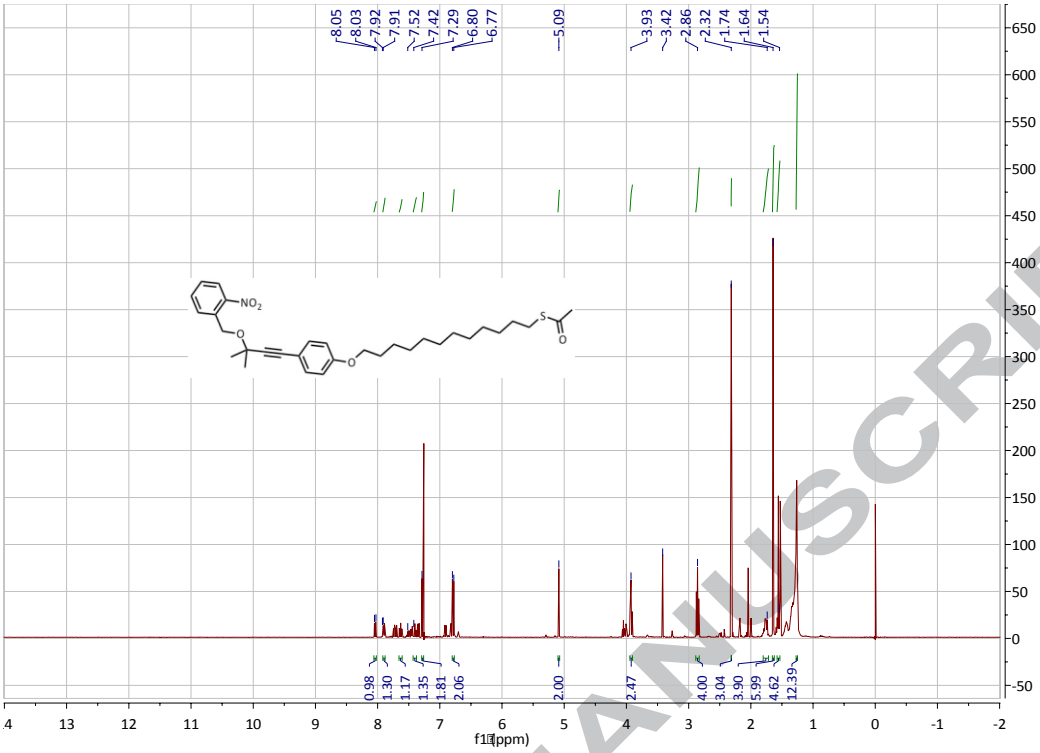


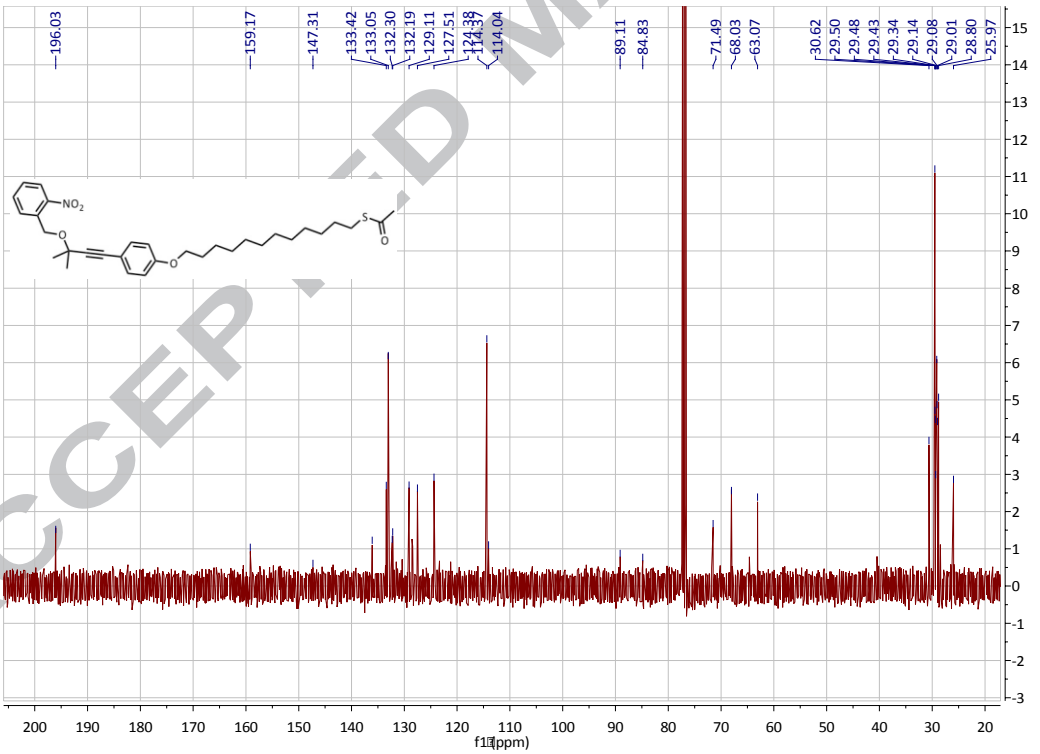


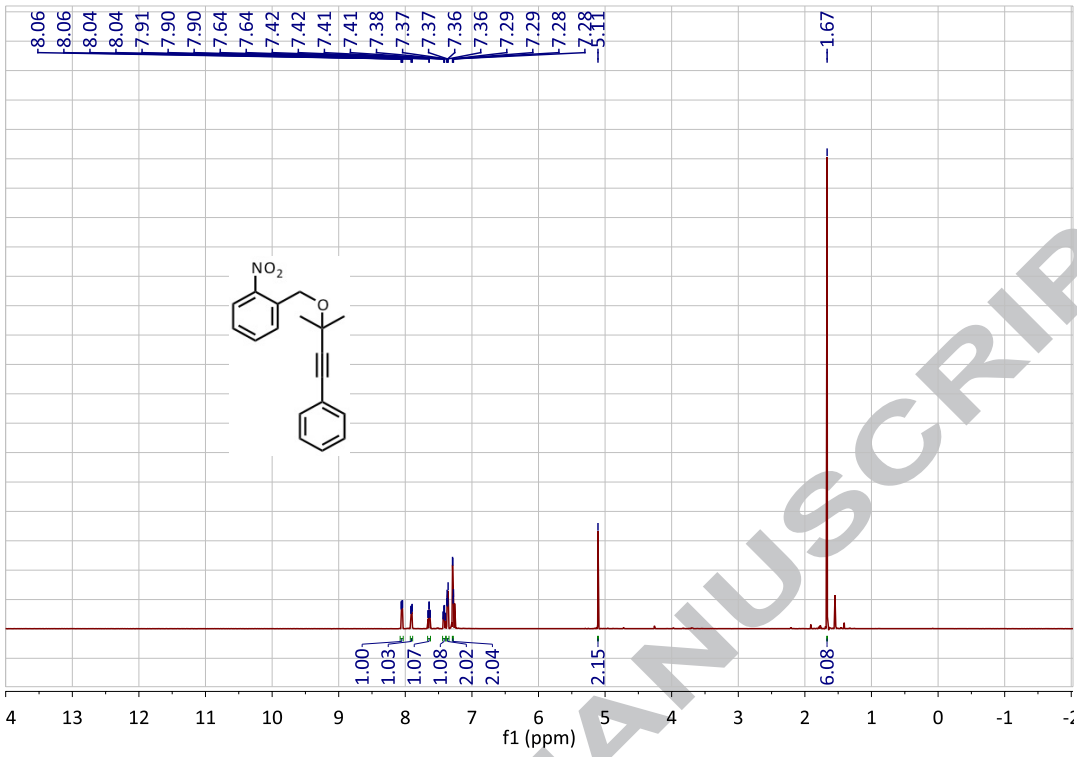


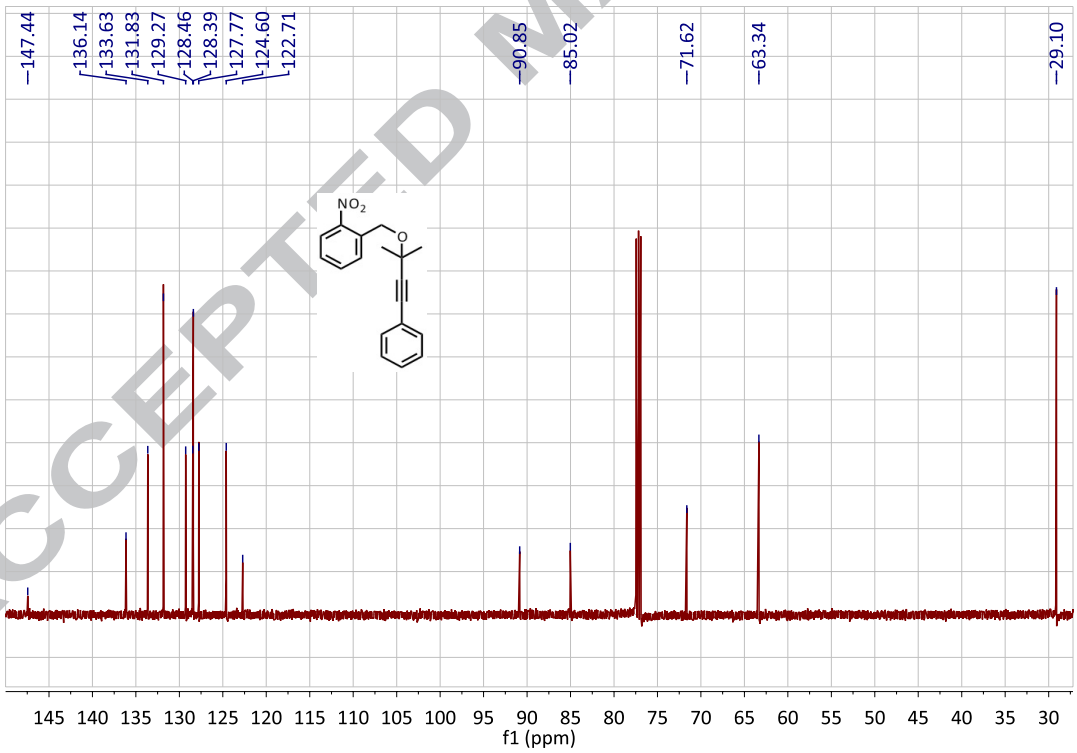


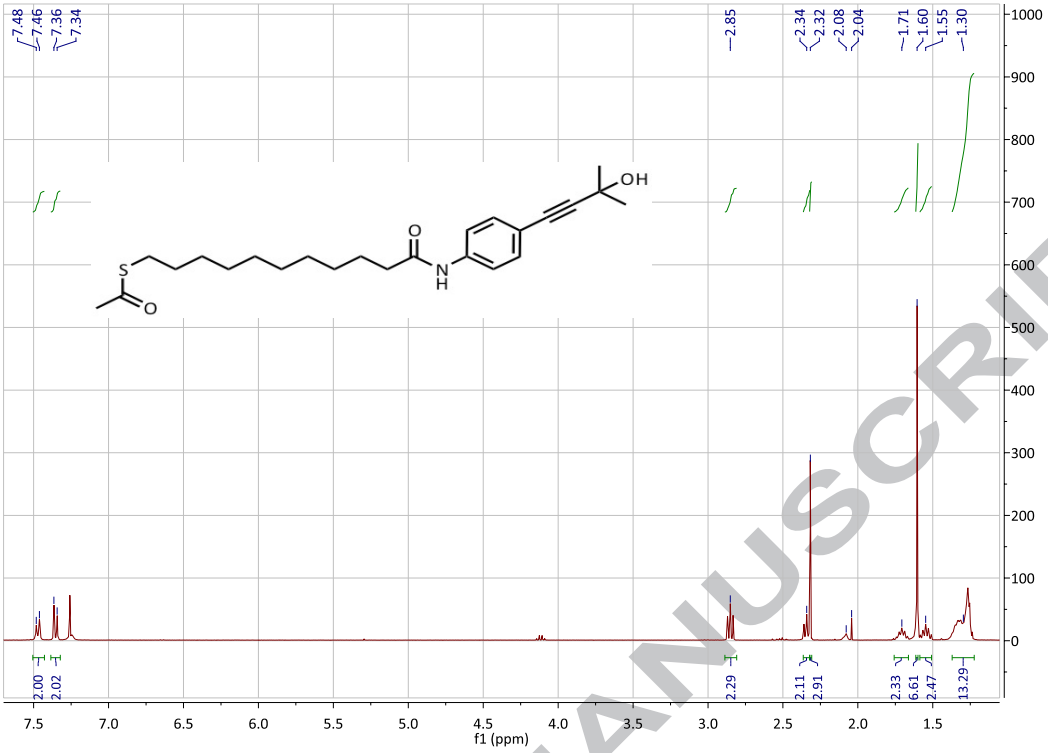


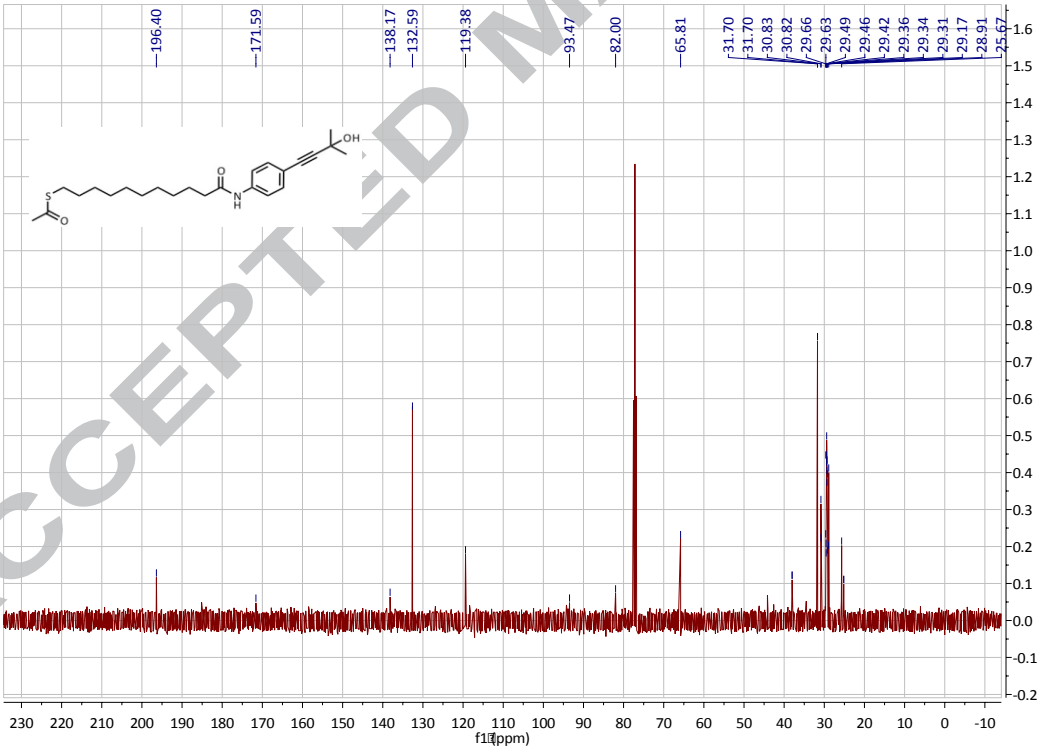


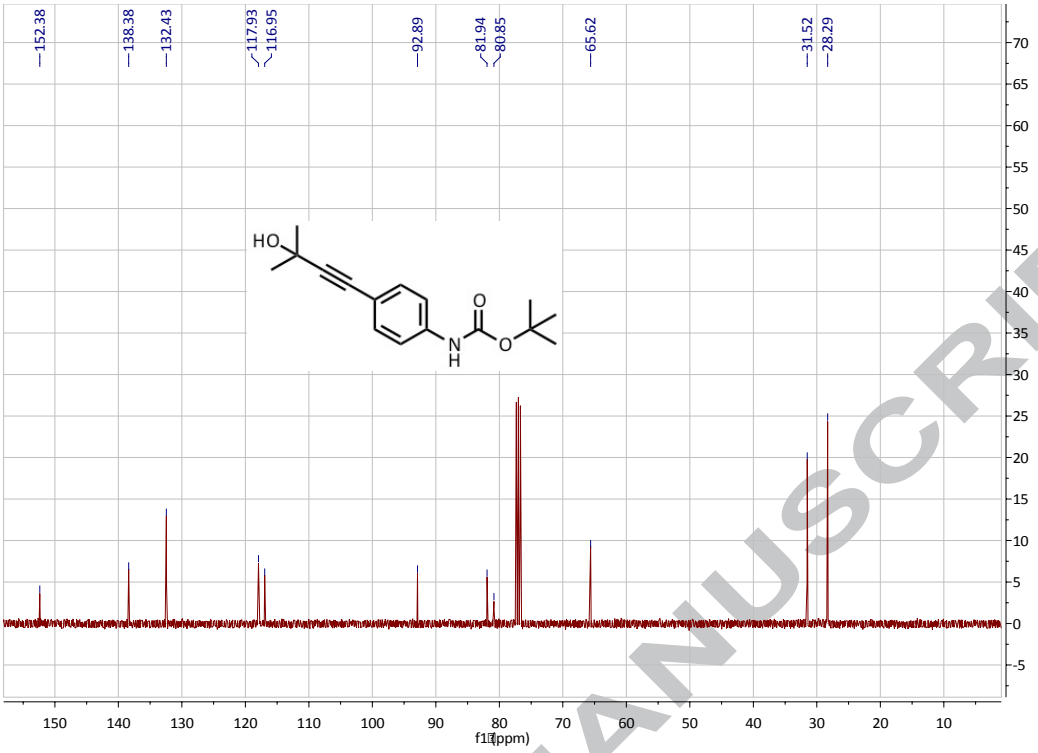


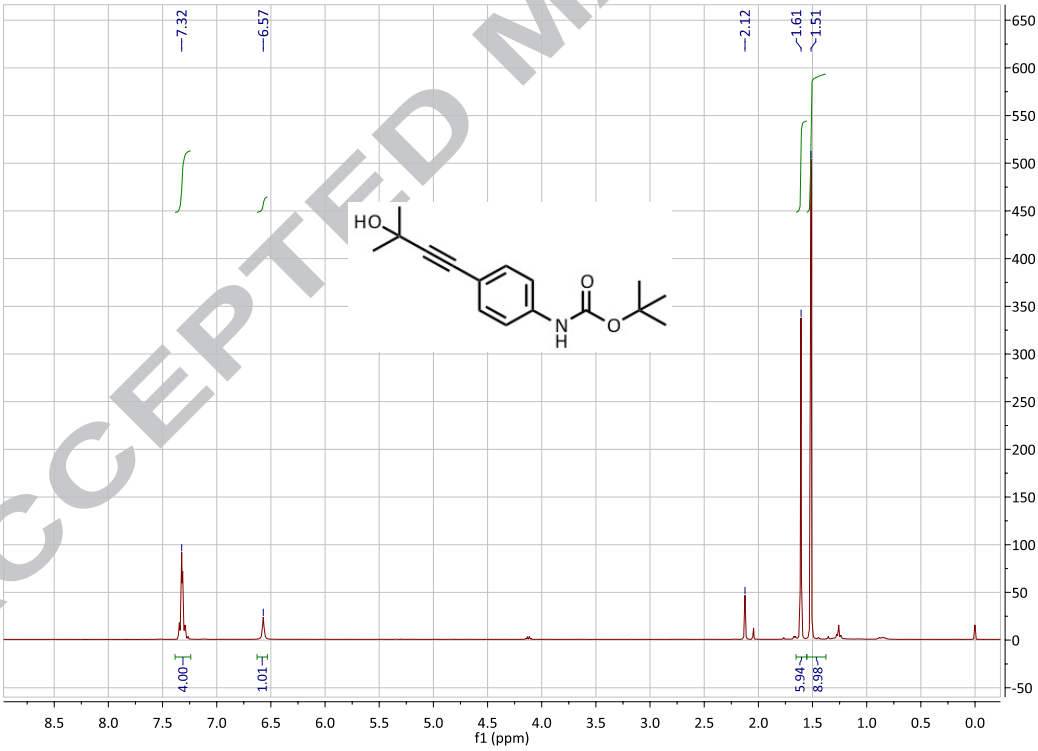


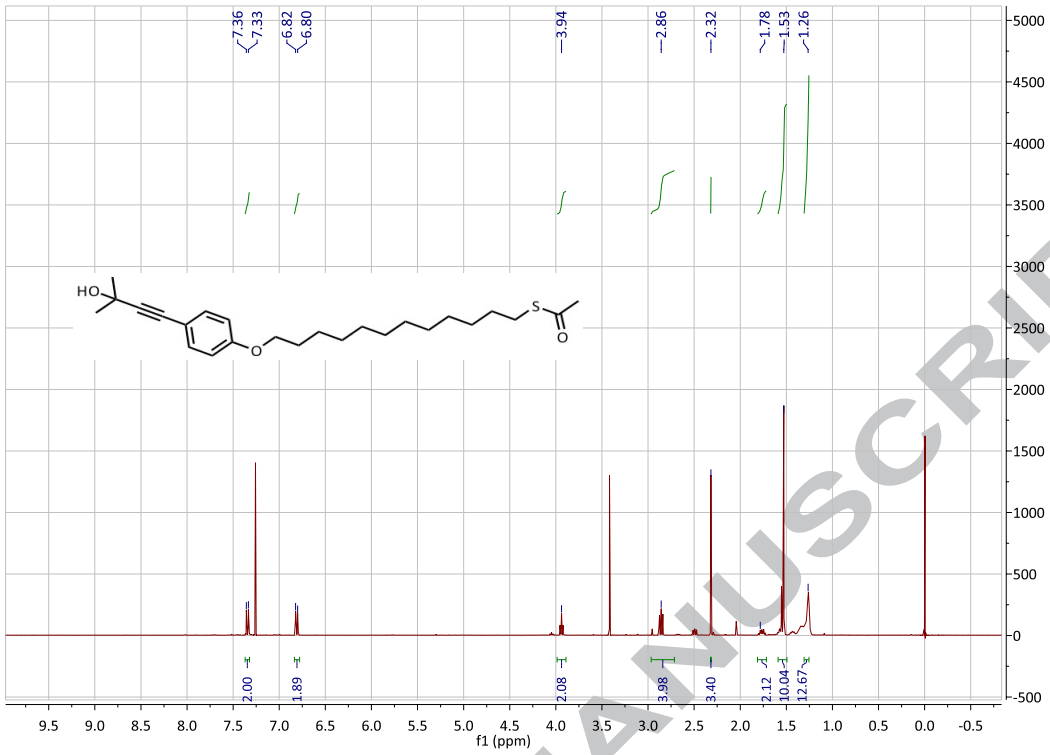


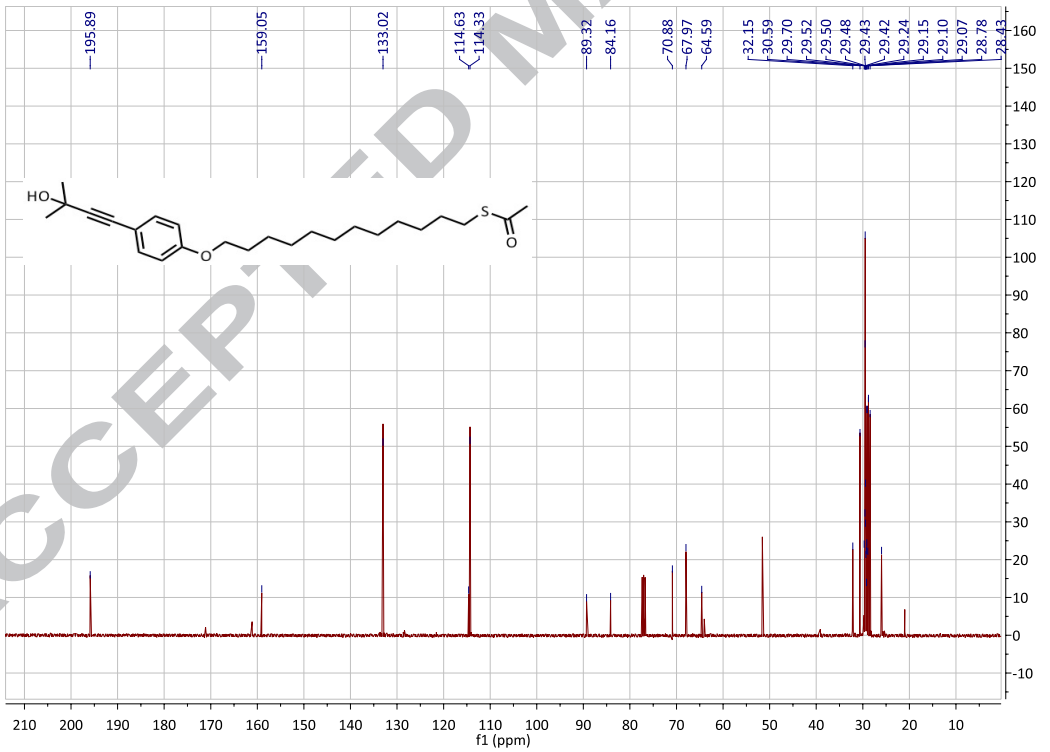


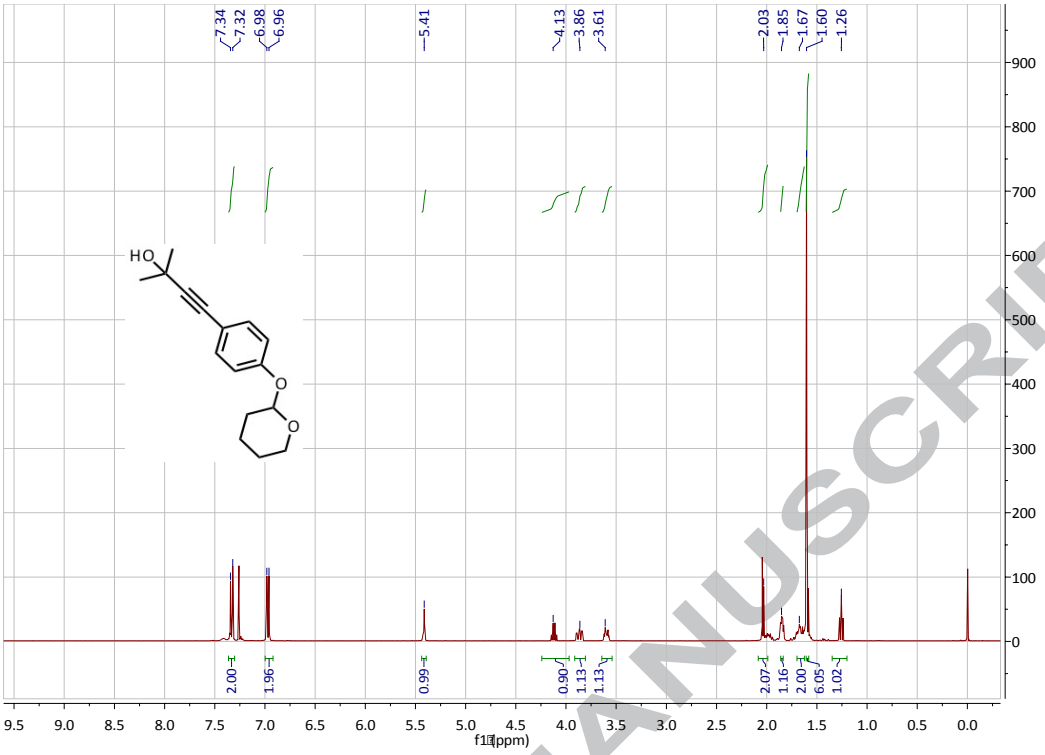


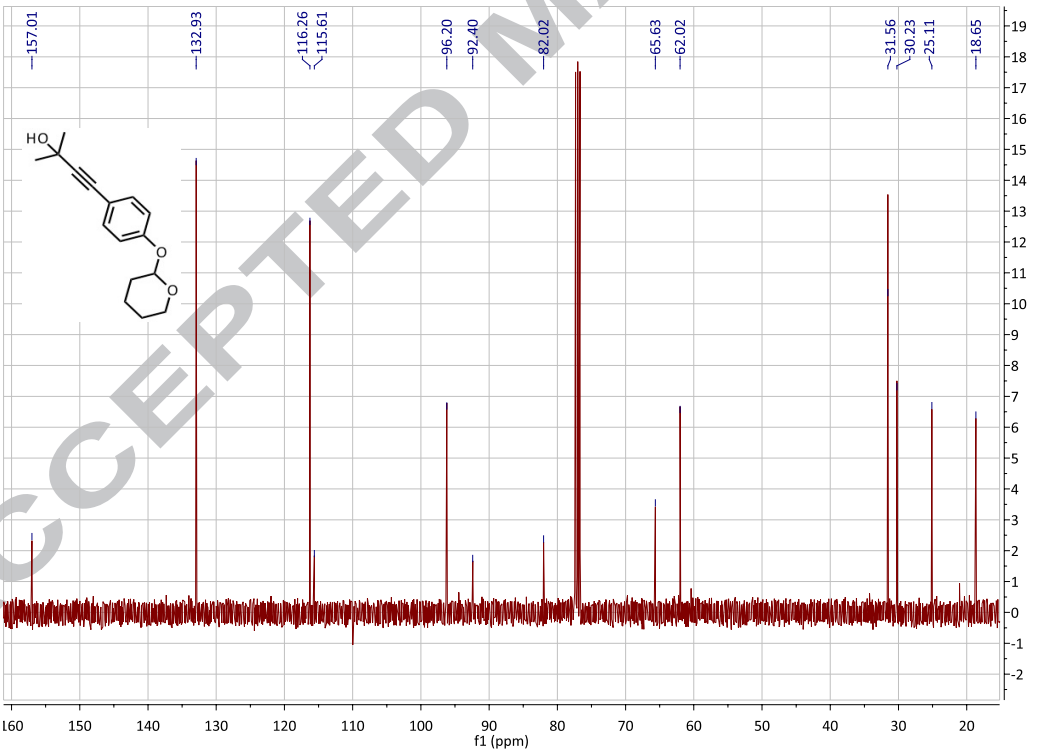


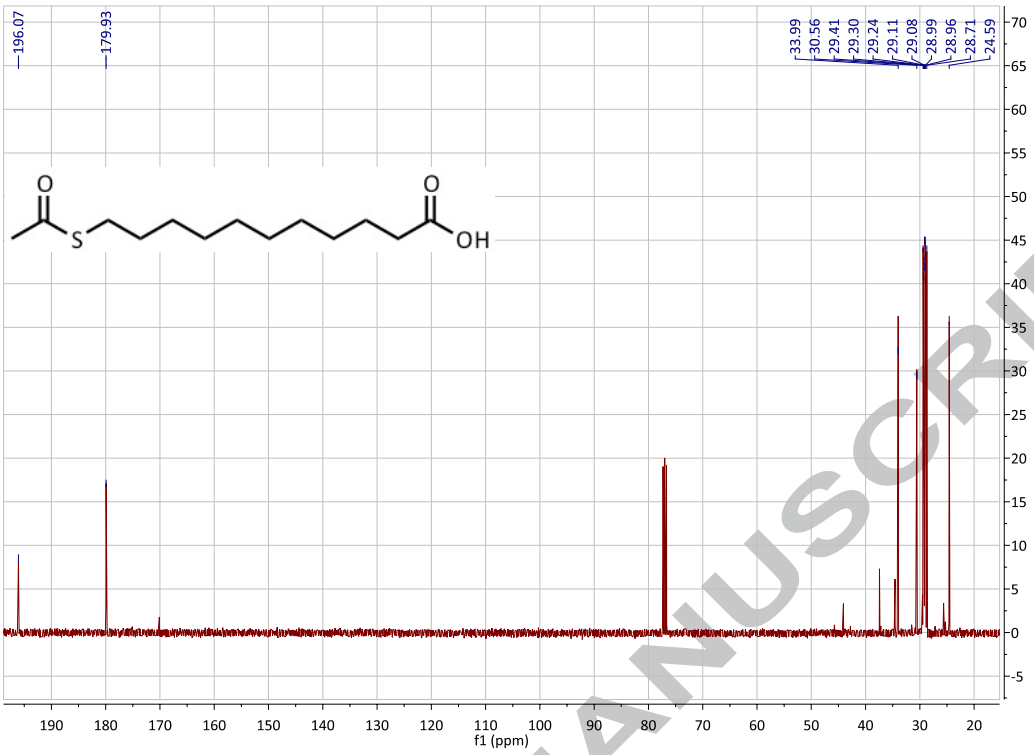


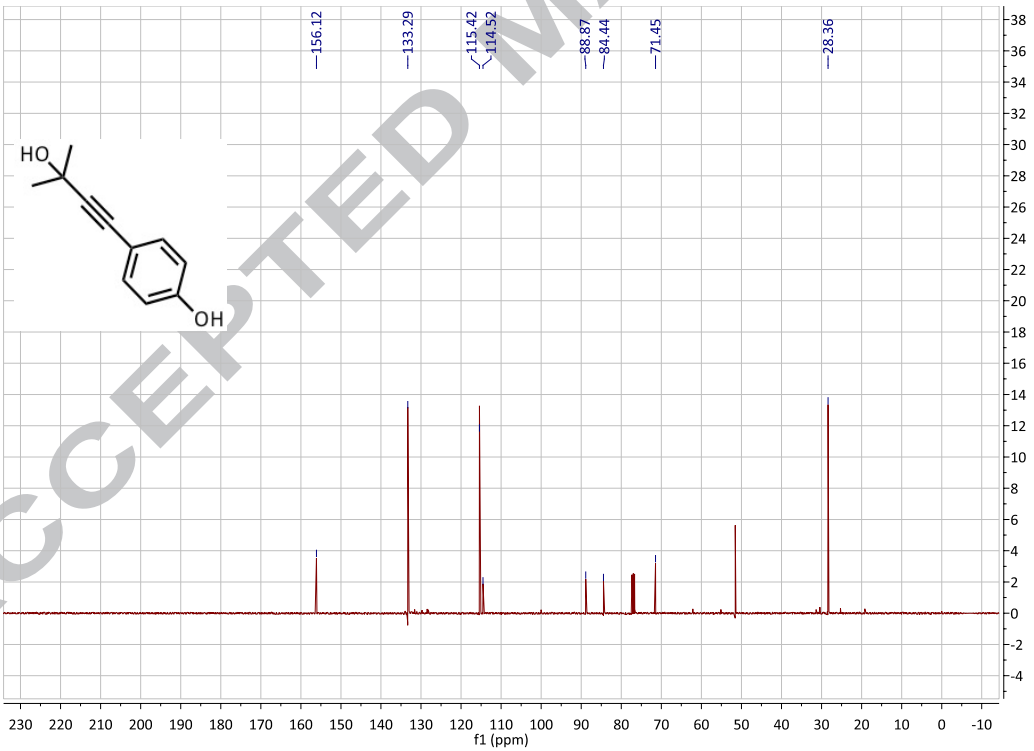


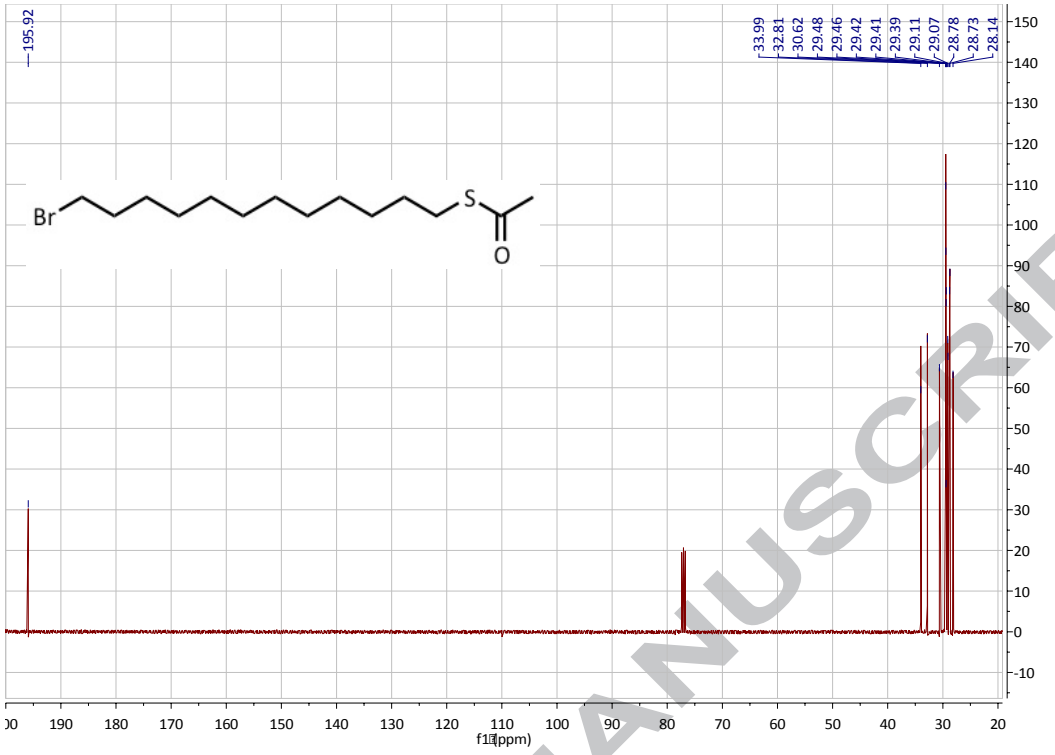


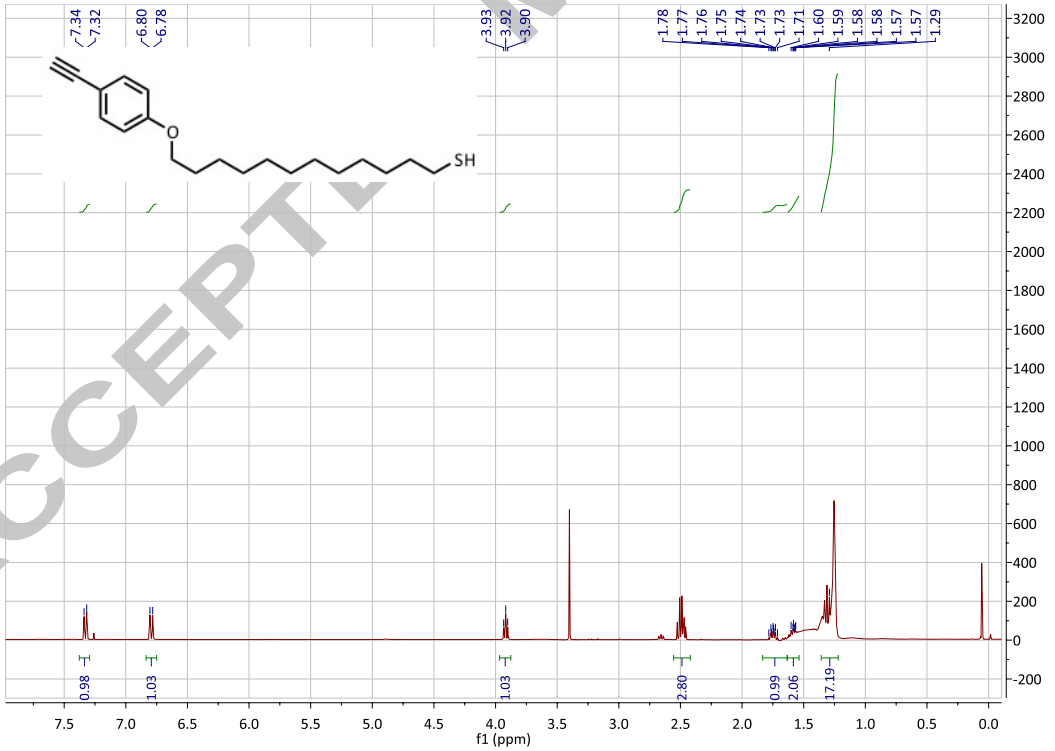


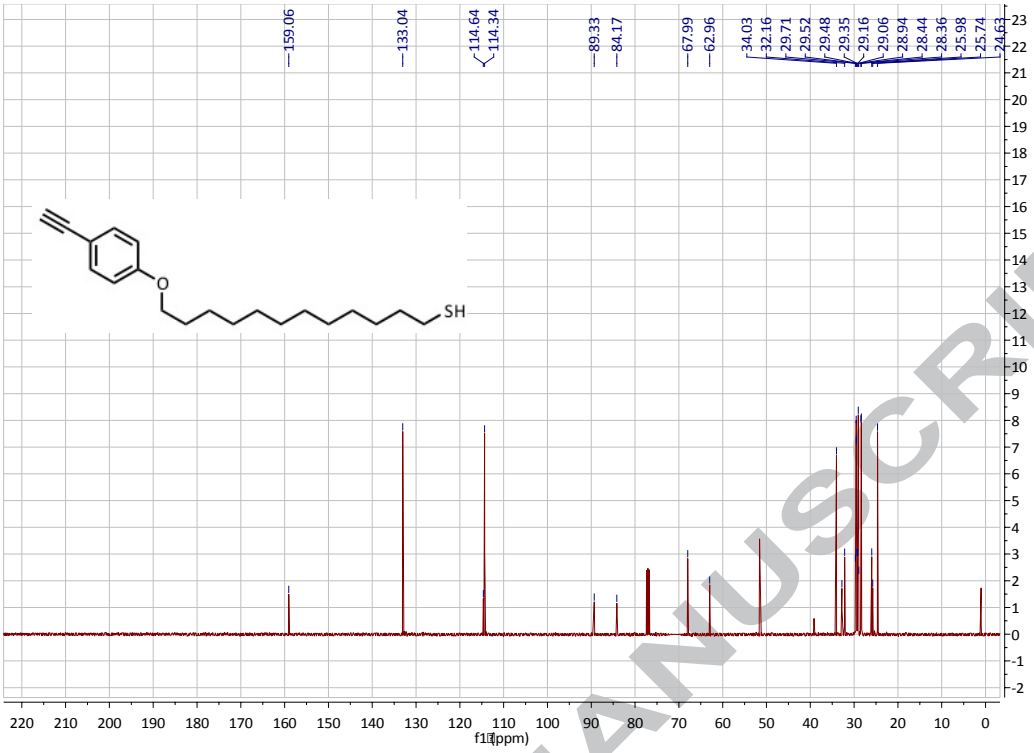












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