Supplementary Information (SI) for Journal of Materials Chemistry B.
This journal is © The Royal Society of Chemistry 2025

Light-activated spatiotemporal control over nanoreactor permeability

Wouter P. van den Akker[1,2], Levena Gascoigne[2], Alexander B Cook,[1] Rolf A.T.M van Benthem[3,4], Ilja K. Voets[2], Jan C.M. van Hest[1]

Supplementary Information

[1]Department of Chemistry & Chemical Engineering, Institute for Complex Molecular Systems, Bio-Organic Chemistry, Eindhoven University of Technology, Helix, P.O. Box 513, 5600MB Eindhoven (The Netherlands)

[2]Department of Chemistry & Chemical Engineering, Self-Organizing Soft Matter
Eindhoven University of Technology, P.O. Box 513, 5600MB Eindhoven (The Netherlands)

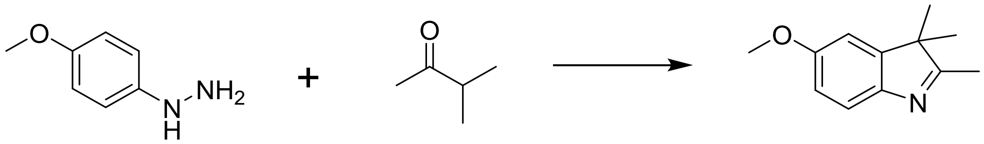
[3]Department of Chemistry & Chemical Engineering, Laboratory of Physical Chemistry. Eindhoven University of Technology, 5600MB Eindhoven (The Netherlands)

[4]Shell Energy Transition Center Amsterdam
Grasweg 31, 1031 HW Amsterdam (The Netherlands)

Corresponding Author
j.c.m.vanhest@tue.nl

1. Synthesis

1.1 Synthesis of **5-methoxy-2,3,3-trimethyl-3*H*-indole**

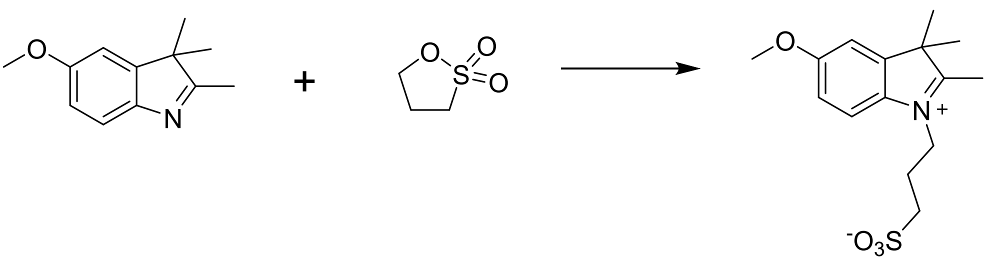


In a 250-ml round bottom flask, p-methoxyphenylhydrazine hydrochloride (5.12 g, 29.3 mmol) and isopropyl methyl ketone (3.8 ml, 35.0 mmol) were dissolved in glacial acetic acid (85 mL) and the mixture was heated to reflux under N_2 atmosphere for 24 h. After evaporation of the solvent under reduced pressure, the residues were dissolved in DCM and the resulting organic layer washed with brine (3 × 100 mL), satd. Na_2CO_3 (3 × 100 mL) and dried over anhydrous $MgSO_4$. Solvent was removed under reduced pressure and the crude product purified by flash chromatography (SiO_2, heptane/EtOAc 2:1) to yield 5-methoxy-2,3,3-trimethyl-3*H*-indole.

^{1}H NMR (399 MHz, DMSO-d6) δ(ppm) : 7.30 (d, 1H), 7.03 (d, 1H), 6.80 (dd, 1H), 3.76 (s, 3H), 2.15 (s, 3H), 1.22 (s, 6H)
^{13}C NMR(101MHz, DMSO-d6) δ(ppm): 185.72, 157.85, 148.01, 119.93, 112.66, 108.64, 55.90, 53.78, 23.12, 15.37

MS (m/z)
Calculated [M+H]: 190.12, found 190.17

1.2 Synthesis of **5-methoxy-2,3,3-trimethyl-3*H*-indolium-propyl-sulfonate**

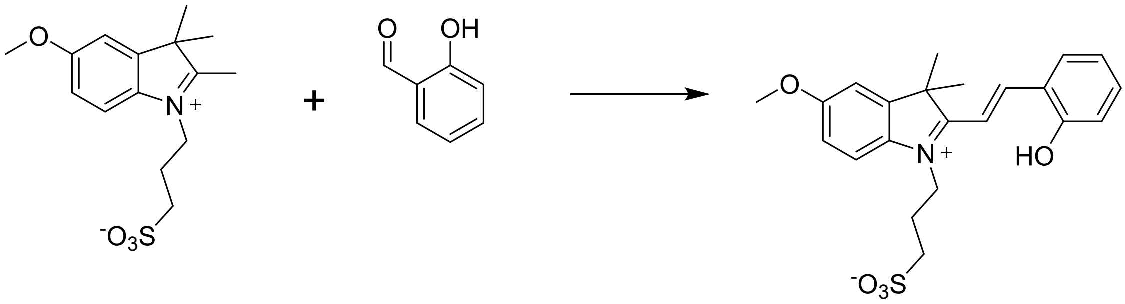


In a 100-mL round bottom flask 1 g (5.27 mmol) of 5-methoxy-2,3,3-trimethyl-3*H*-indole and 1.1 g (9 mmol) of 1,3-propanesultone were dissolved in MeCN (20 mL) and the solution heated to reflux for 16 h. The resulting mixture was cooled down to room temperature and added dropwise to 200 mL EtOAc under stirring, leading to a whitegreen precipitate. The solid was separated by vacuum filtration and washed with EtOAc (3 × 10 mL), yielding 5-methoxy-2,3,3-trimethylindolium-propyl-sulfonate as purple solid (862 mg, 52.8% yield).

^{1}H NMR (399 MHz, DMSO-d6) δ(ppm) : 7.95 (d, 1H), 7.45 (d, 1H), 7.15 (dd, 1H), 4.60 (t, 2H), 3.86 (s, 3H), 2.76 (s, 3H), 2.60 (t, 2H), 2.12 (m, 2H), 1.50 (s, 6H)
^{13}C NMR(101MHz, DMSO-d6) δ(ppm): 194.01, 161.05, 144.47, 134.86, 116.90, 114.77, 109.86, 56.53, 54.38, 47.80, 47.02, 24.33, 22.60, 13.97

MS (m/z)
Calculated [M+H]: 312.12, found 312.58

1.3 Synthesis of **1**

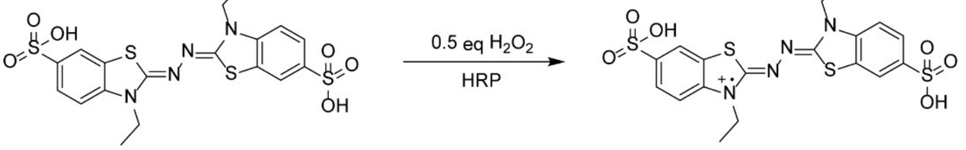


In a 50-mL round-bottom flask 720 mg (2.3 mmol) MeO-2,3,3-trimethylindolium-propyl-sulfonate was dissolved in absolute EtOH (ca. 20 mL/g). Salicylaldehyde (122 g/mol) (2 equivalents) was added, the flask sealed with a septum and the solution degassed by gentle N_2 bubbling (10 min) prior to heating it up to 90 °C under stirring for 24 h. The resulting orange precipitate was filtered, and washed thoroughly with EtOH to remove unreacted materials to yield **1** (450 mg, 47% yield)

^{1}H NMR (399 MHz, DMSO-d6) δ(ppm) : 10.92 (s, 1H), 8.50 (d, 1H), 8.24 (dd, 1H), 7.95 (d, 1H), 7.81 (d, 1H), 7.51 (d, 1H), 7.44 (m, 1H), 7.17 (dd, 1H), 7.02 (d, 1H), 6.97 (t, 1H), 4.77 (t, 2H), 3.89 (s, 3H), 2.63 (t, 2H), 2.16 (p, 2H), 1.76 (s, 6H)
^{13}C NMR(101MHz, DMSO-d6) δ(ppm): 179.95, 161.20, 159.10, 147.22, 146.18, 135.65, 134.66, 130.00, 121.89, 120.47, 117.02, 116.71, 115.35, 112.04, 109.32, 56.62, 56.49, 52.30, 47.80, 46.06, 26.91, 25.19

MS (m/z)
Calculated [M+H]: 416.15, found 416.50

2. Supplementary Figures.



Scheme 1 : Enzymatic conversion of 2,2′-azino-bis(3-ethylbenzothiazoline-6-sulfonic acid) to ABTS^{*+} by horse radish peroxidase

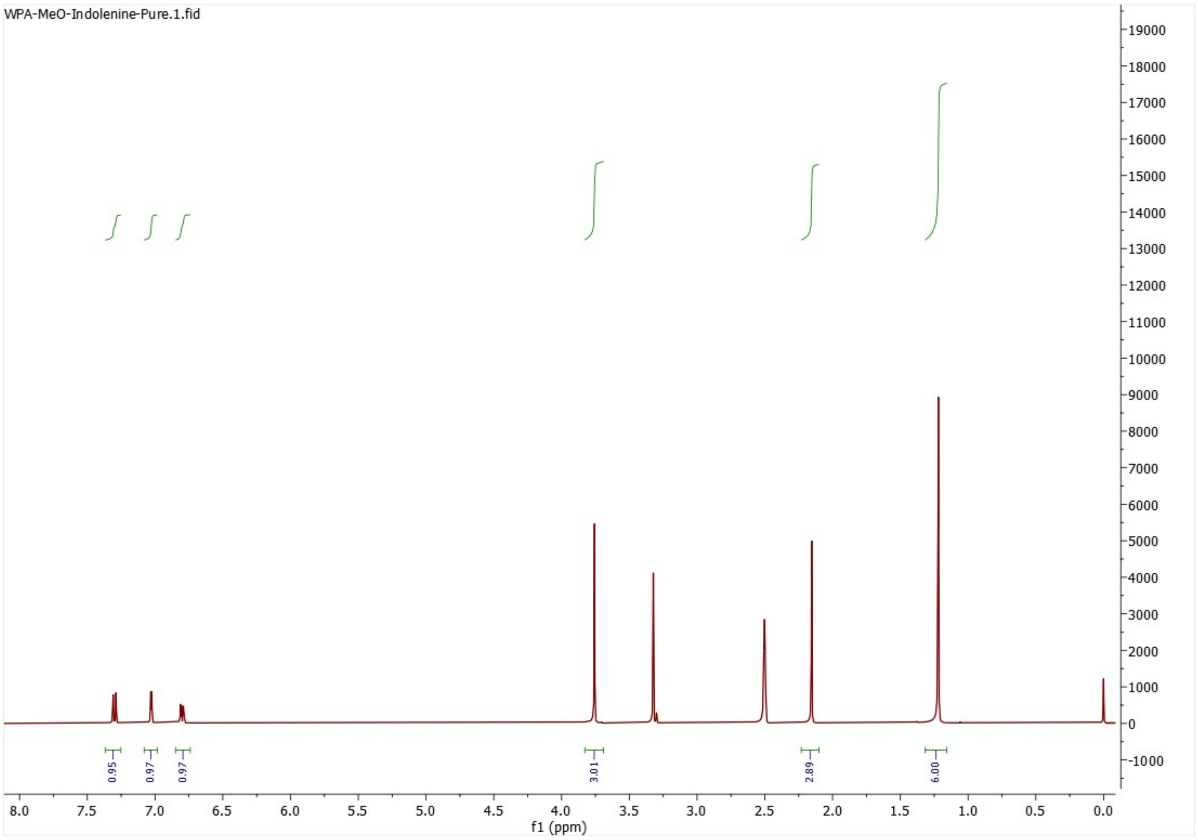


Figure S1 – ^{1}H NMR spectrum of 5-methoxy-2,3,3-trimethyl-3*H*-indole.

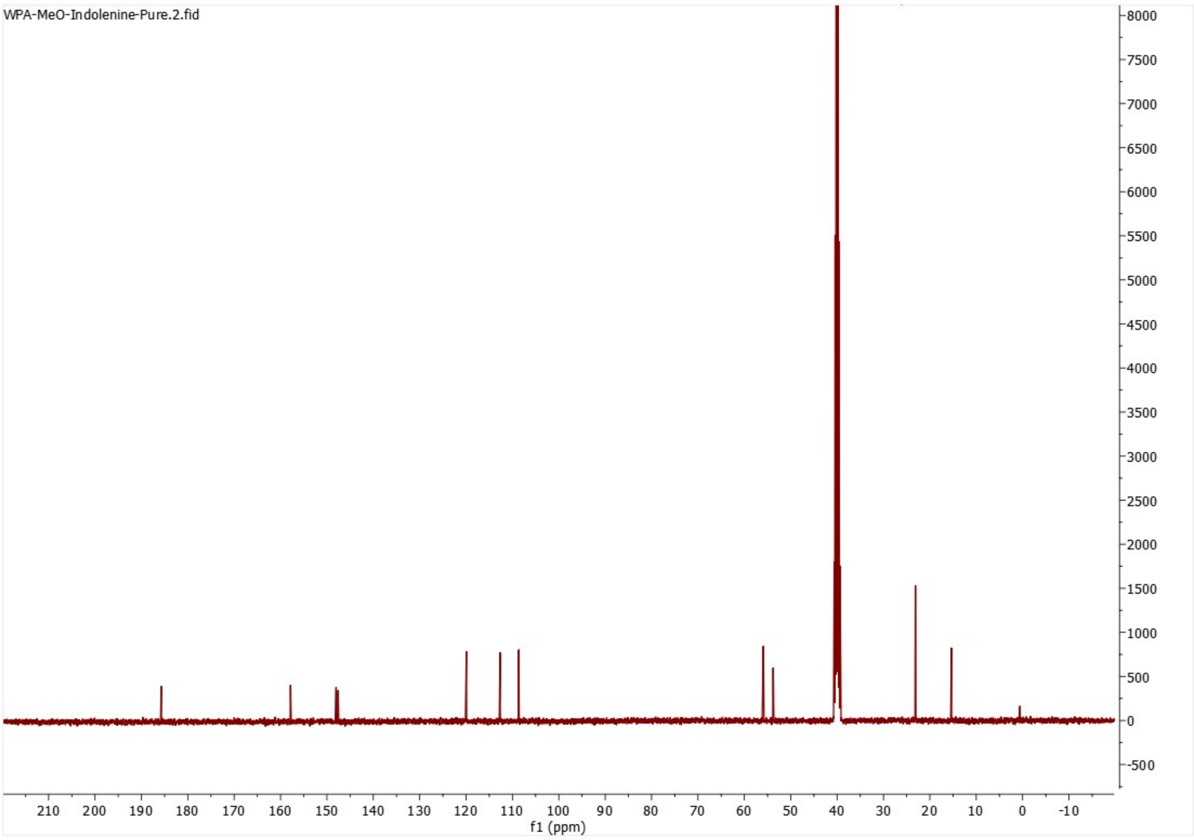


Figure S2 – ^{13}C NMR spectrum of 5-methoxy-2,3,3-trimethyl-3*H*-indole.

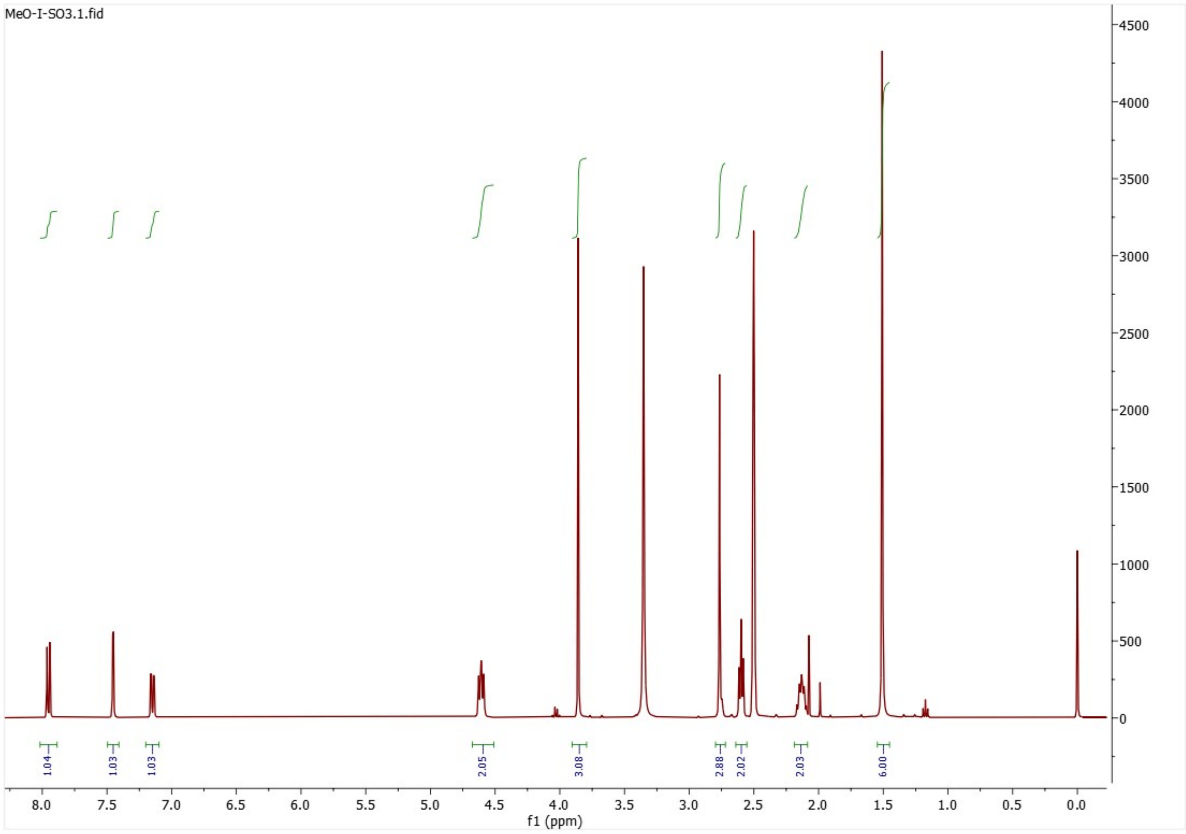


Figure S3 – ^{1}H NMR spectrum of MeO-2,3,3-trimethylindolium-propyl-sulfonate

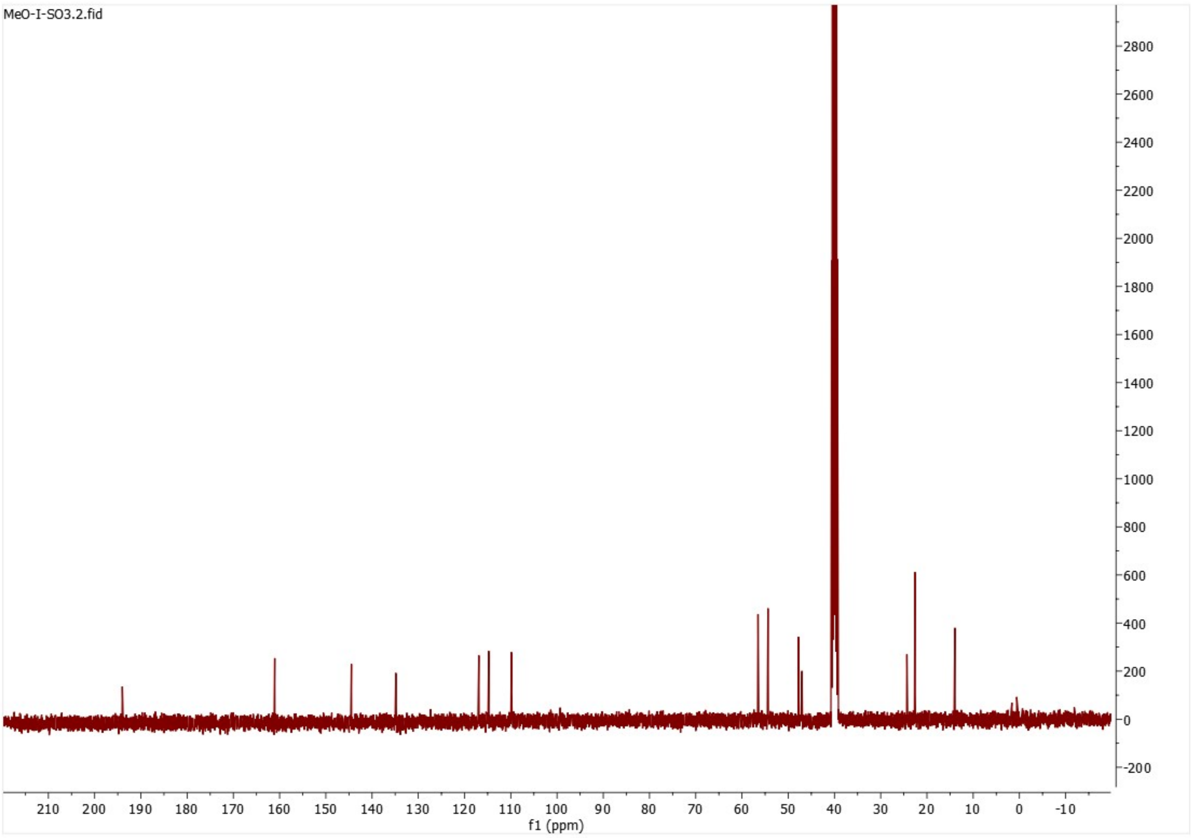


Figure S4 – ^{13}C NMR spectrum of MeO-2,3,3-trimethylindolium-propyl-sulfonate

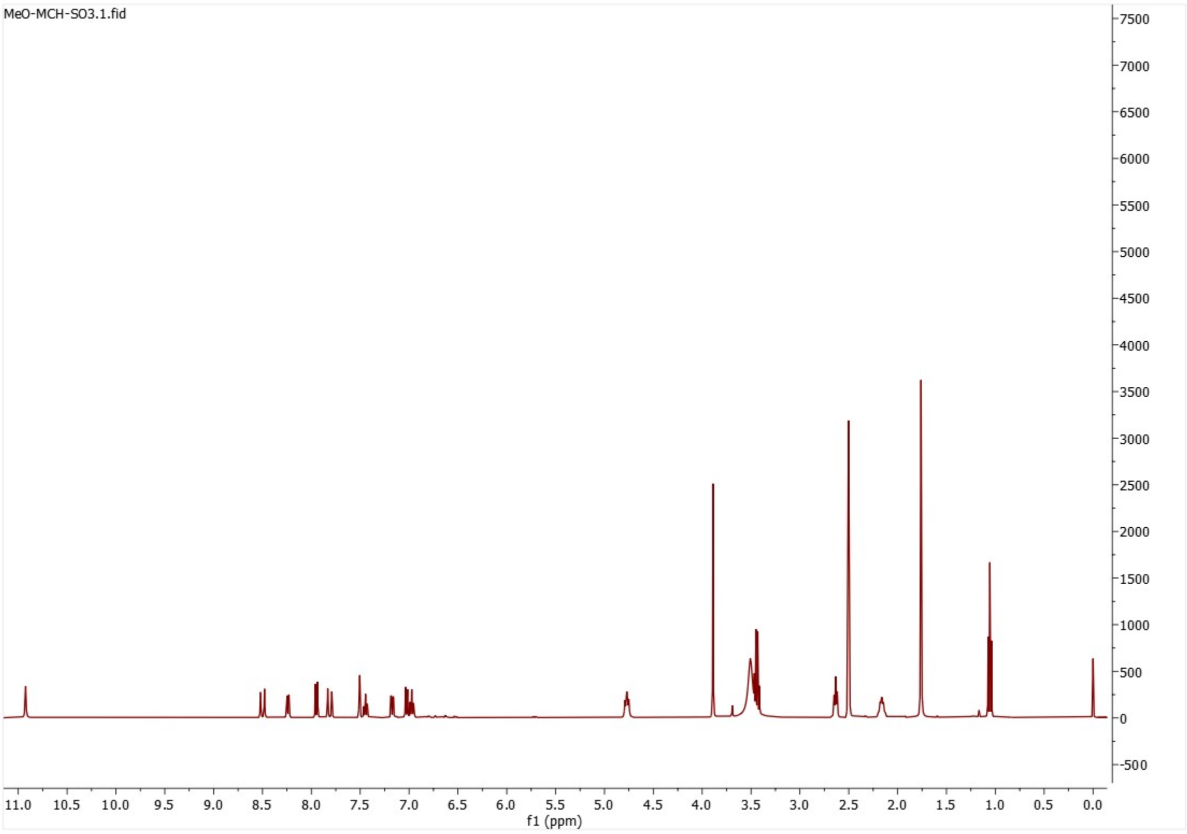


Figure S5 – ^{1}H NMR spectrum of **1**

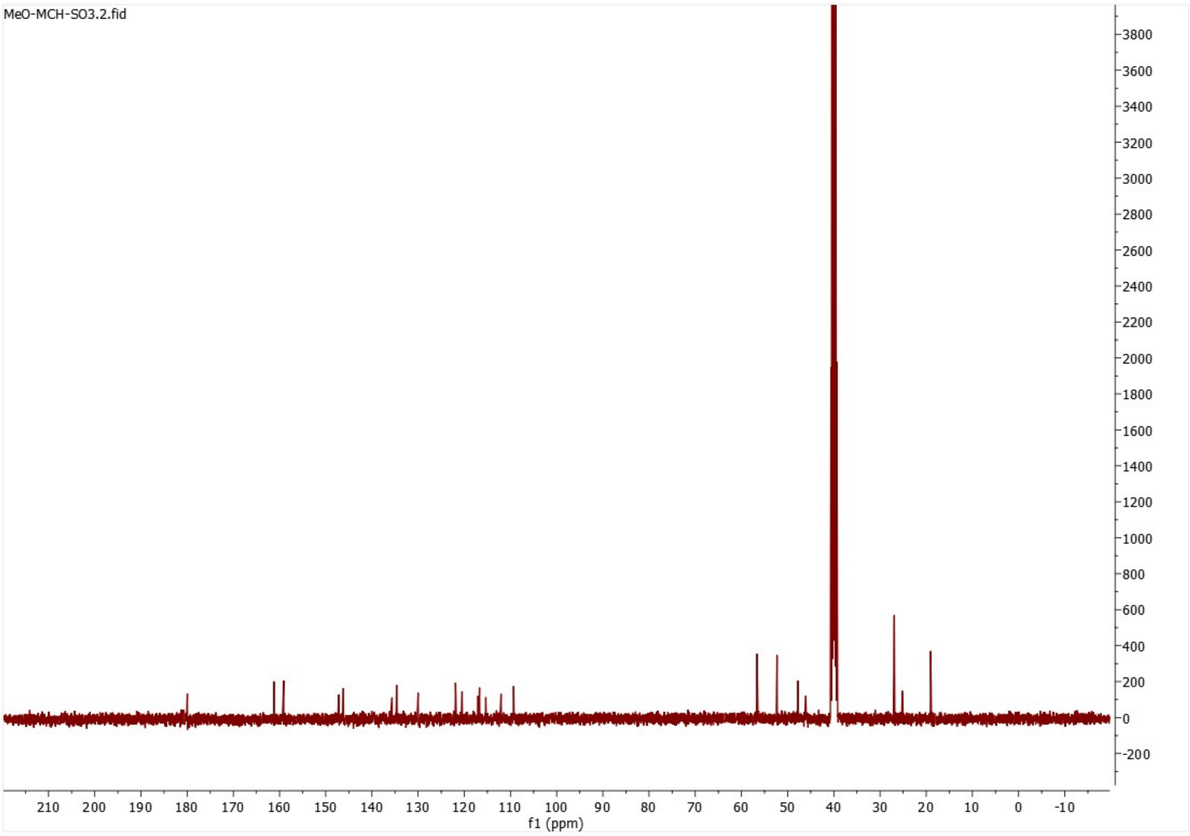


Figure S6 – ^{13}C NMR spectrum of **1**

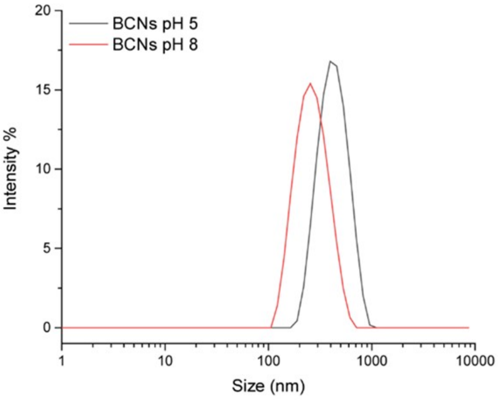


Figure S7. Dynamic Light Scattering characterization of BCNs at both pH 8 and pH 5.

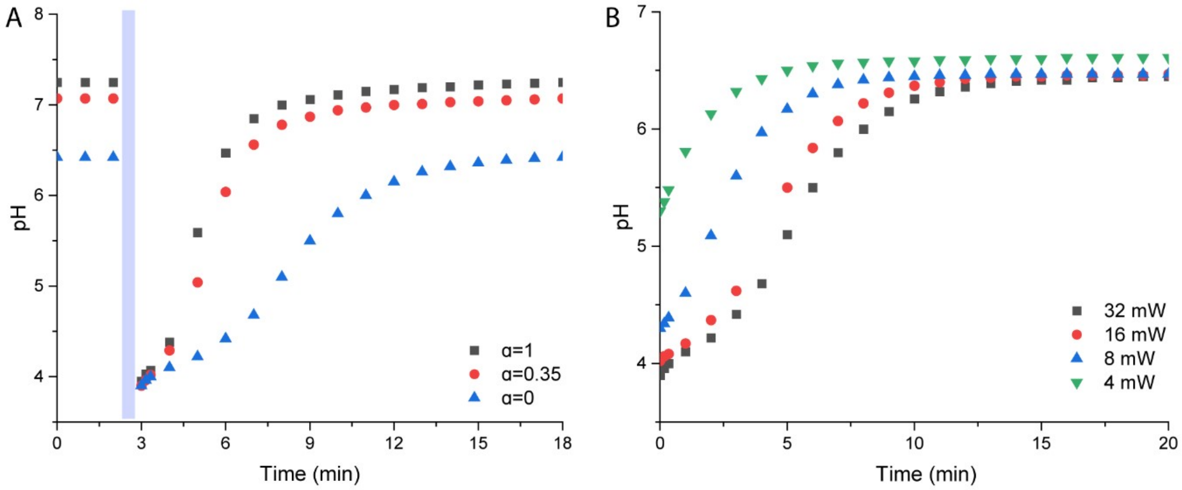


Figure S8. A) influence of neutralization factor α on merocyanine photoacid behavior. B) Influence of light intensity on pH-switching behavior. Lower light intensities are unable to decrease the pH to the lowest value.

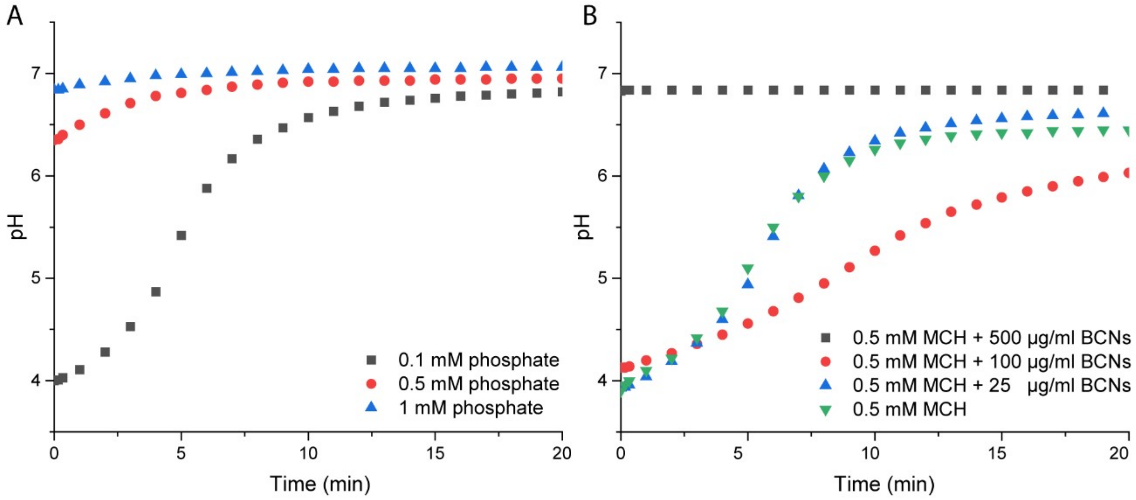


Figure S9. A) Influence of phosphate buffer capacity on pH-switching behavior. B) Influence of BCN concentration on pH-switching behavior of **1**. [**1**] = 0.5 mM. (α=0)

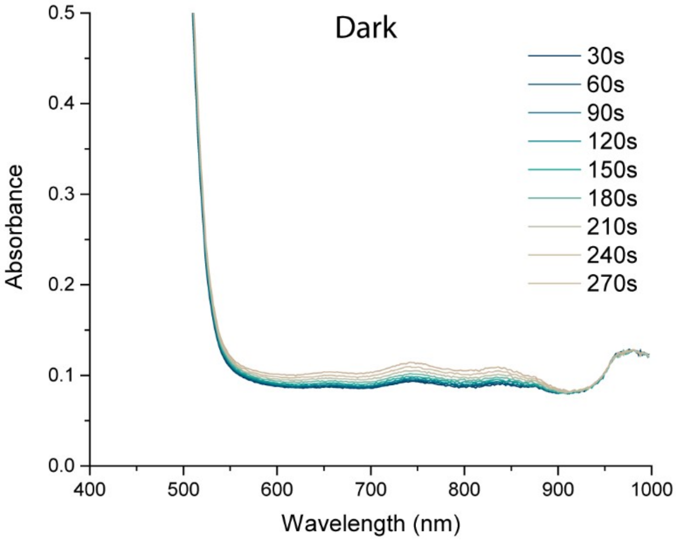


Figure S10. ABTS conversion of HRP loaded BCNs embedded within a hydrogel while kept in the dark. 1 mM [MCH].

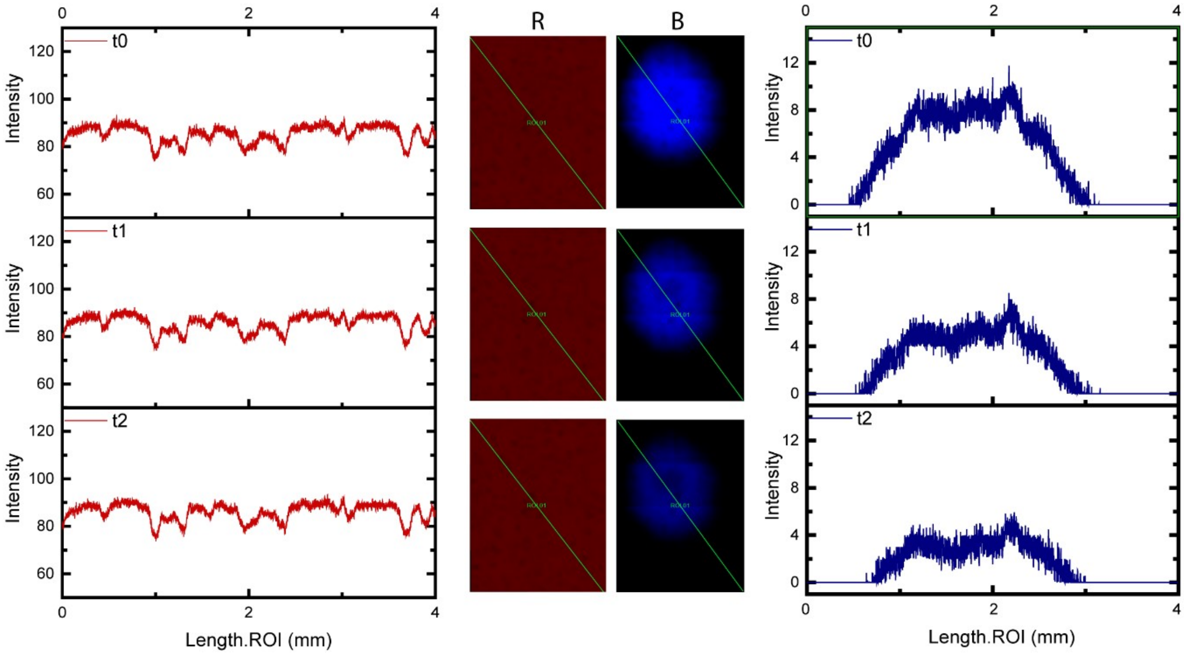


Figure S11 : Comparison between blue & red channel without ABTS substrate. Irradiation using the 480 nm laser line does not influence the red channel in absence of substrate.

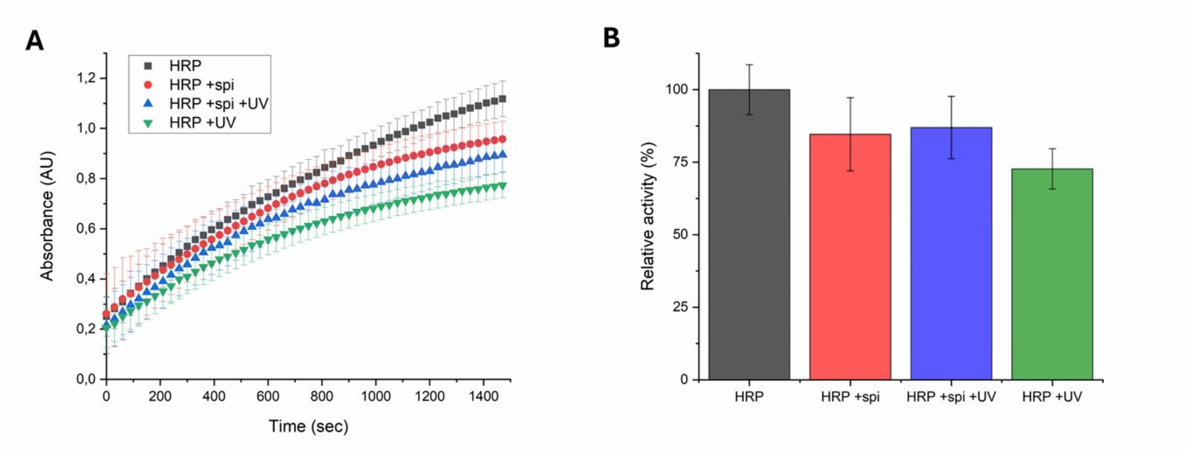


Figure S12 : Influence of spiropyran and spiropyran induced pH change on the HRP activity. A) Production of ABTS+ via absorbance at 415 nm, B) the slopes were determined for the first 150 seconds in the linear regime, and the relative activities were calculated. The most active condition was normalized as 100% relative activity. The HRP substrate conversion does not change significantly at the varied conditions. Merocyanine was irradiated at 405 nm for 5 min.

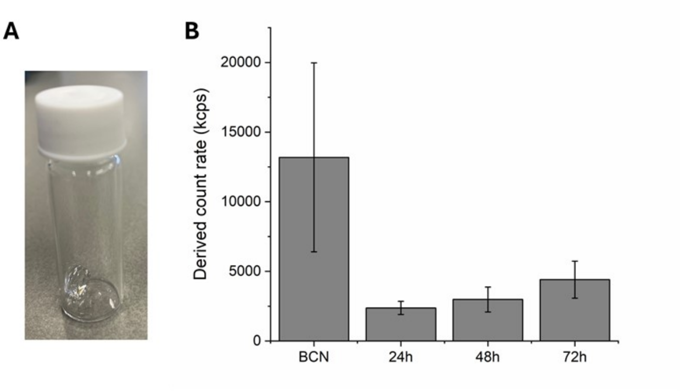


Figure S13 : A) Image of BCN loaded hydrogel, B) Investigation of BCN leakage from hydrogel. BCN loaded hydrogels (100 uL, 96 well plate mould), formed from 10 wt% acrylamide (50:1 methylenebisacrylamide crosslinker), immersed in water for various time points, and the supernatant derived count rate check with DLS for an indication of free particles.