

## Supplementary Material

### Nitrosonium-Mediated Phenol-Arene Cross-Coupling Involving Direct C-H Activation

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## General Information and Materials

Commercial reagents and starting materials were purchased and used without further purification. NMR-spectra were recorded on a Varian INOVA 400 ( $^1\text{H}$  at 400 MHz and  $^{13}\text{C}$  at 100 MHz) using the solvent residual peak as internal reference ( $\text{CDCl}_3$ :  $\delta$  H 7.26;  $\delta$  C 77.0). Chemical shifts  $\delta$  are reported in ppm. Multiplicities are indicated, s (singlet), d (doublet), t (triplet), q (quartet), quint (quintet), sept (septet), m (multiplet); coupling constants ( $J$ ) are given in Hertz (Hz). Reactions were monitored by thin-layer chromatography (aluminium-backed 2 mm thick silica gel 60 F<sub>254</sub>); visualization was accomplished with UV light (254 nm or 366 nm). Flash column chromatography was performed on a Biotage Isolera One automated flash purification system with UV-vis detector using silica gel 60 for normal phase chromatography. CV measurements were conducted with the three-electrode potentiostat galvanostat PGSTAT302N from Metrohm Autolab. A glassy carbon working electrode and a platinum counter electrode were used. As reference electrode a silver wire was used. The potentials were determined relative to the  $\text{Fc}/\text{Fc}^+$  redox couple with ferrocene as internal standard.

Photocatalytic reactions were performed with blue LEDs (Osram Oslon SSL 80,  $\lambda_{\text{Peak}} = 440$  nm, royal blue, operated at 700 mA). The illumination setup consisted of a LED array and a temperature control unit. The samples were irradiated through the vial's plane bottom side and cooled from the side using custom made aluminium blocks connected to water cooling.

## GC-MS Investigations

GC-MS measurements were performed on a 7890A GC system from Agilent Technologies with an Agilent 5975 MSD Detector. Data acquisition and evaluation was done with MSD ChemStation E.02.02.1431. The GC-MS oven temperature program was adjusted as follows: initial temperature 70 °C was maintained for 5 min, the temperature was increased at a rate of 10 °C/min over a period of 18 min until the final temperature (250 °C) was reached and maintained for 17 min.

For quantitative GC-MS measurements a calibration was performed using the internal standard method (multi-level calibration, internal standard: 2-methylnaphthalene). Authentic samples of each compound were used for calibration.

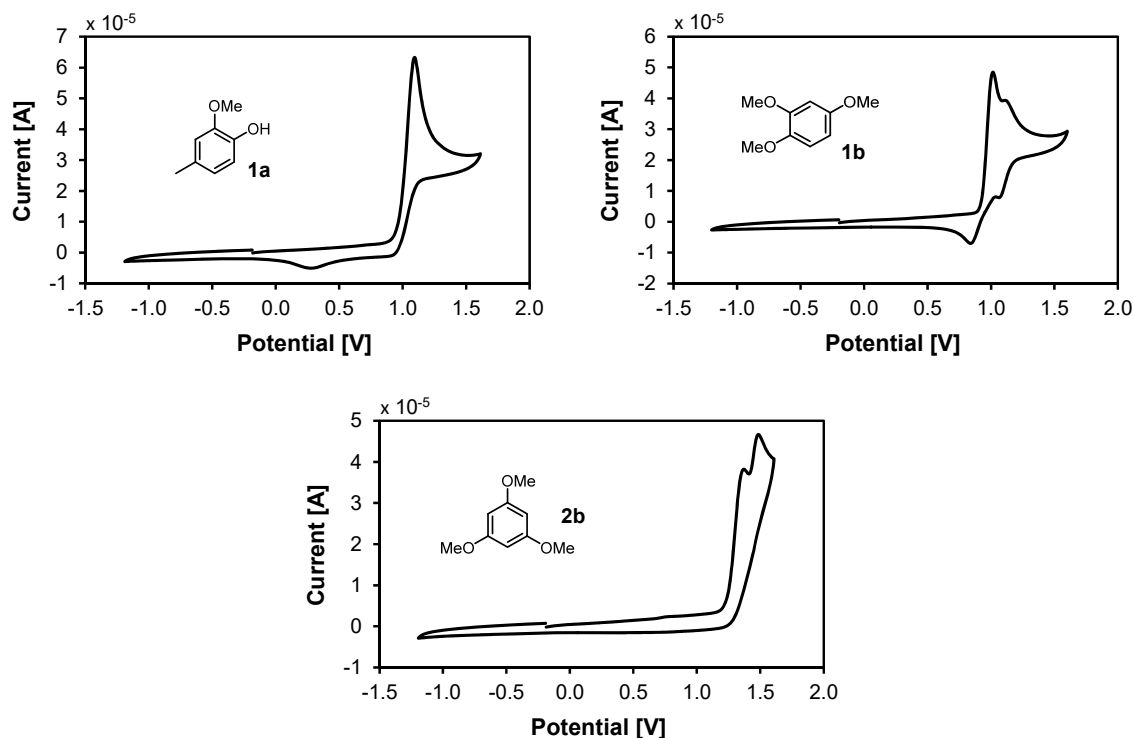
*General procedure for quantitative GC-MS investigations:* In a snap vial equipped with a magnetic stirring bar the respective amount of LiNO<sub>3</sub> and 5 mol% 9-mesityl-10-methylacridinium perchlorate **1** (if mentioned) were dissolved in 1 mL of the formic acid/MeOH mixture (method of MeOH addition and ratio as indicated). The arene **1b** (3.0 equiv., 0.70 mmol) and phenol component **1a** (1.0 equiv., 0.23 mmol) were added successively and the resulting mixture was stirred at rt open to air for the indicated time. If mentioned the sample was irradiated through the vial's plane bottom side with blue LEDs. After the addition of 2-methylnaphthalene as internal standard, the sample was filtered over a small plug of silica gel. The plug was rinsed with MeOH (1:1), diluted and submitted to GC-MS.

*General procedure for qualitative GC-MS investigations:* In a snap vial equipped with a magnetic stirring bar the respective amount of LiNO<sub>3</sub> and 5 mol% 9-mesityl-10-methylacridinium perchlorate **1** (if mentioned) were dissolved in 1 mL of the indicated solvent. The arene **b** (3.0 equiv., 0.75 mmol) and phenol component **1a** (1.0 equiv., 0.25 mmol) were added successively and the resulting mixture was irradiated with blue LEDs (if mentioned) through the vial's plane bottom side open to air at rt for the indicated time. The sample was filtered over a small plug of silica gel. The plug was rinsed with MeOH (1:1), diluted with MeOH and submitted to GC-MS.

## Cyclic Voltammetry Measurements

CV measurements were conducted with the three-electrode potentiostat galvanostat PGSTAT302N from Metrohm Autolab. A glassy carbon working electrode and a platinum counter electrode were used. As reference electrode a silver wire was used. The potentials were referenced relative to the Fc/Fc<sup>+</sup> redox couple with ferrocene as internal standard. The control of the measurement instrument, the acquisition and processing of the cyclic voltammetric data were performed with the software Metrohm Autolab NOVA 1.10.4.

The measurements were carried out as follows: 6 mL of a 0.1 M solution of the supporting electrolyte tetrabutylammonium tetrafluoroborate in acetonitrile was placed in the measuring cell and the solution was degassed by a stream of argon for 5 min. After recording of the baseline the electroactive species was added (1 mL of 0.01 M) and the solution was degassed by argon purge for 5 min. The cyclic voltammogram was recorded with one to three scans at a scan rate of 50 mV s<sup>-1</sup>. Finally ferrocene (2.2 mg, 12 μmol) was added to the solution. The solution was degassed by a argon purge for another 5 min and the measurement was performed again with one to three scans. The potentials were converted to SCE according to V. Pavlishchuk and A. W. Addison.<sup>[1]</sup>



**Figure S1.** Cyclic voltammograms of 2-methoxy-4-methylphenol (**1a**), 1,2,4-trimethoxybenzene (**1b**) and 1,3,5-trimethoxybenzene (**2b**).

## Preparation of Authentic Samples for GC-MS Calibration

*General procedure:* In a snap vial equipped with a magnetic stirring bar 0.5 equiv. LiNO<sub>3</sub> and 5 mol% 9-mesityl-10-methylacridinium perchlorate **1** were dissolved in 0.9 mL of formic acid. MeOH (0.1 mL), arene **1b** (3.0 equiv., 0.75 mmol) and phenol **1a** (1.0 equiv., 0.25 mmol) were added successively and the resulting mixture was stirred at rt open to air for 5 h. The sample was irradiated through the vial's plane bottom side with blue LEDs. The solvent was removed by evaporation and the crude residue was purified by automated flash column chromatography (silica gel, hexane/ethyl acetate).

### *2-Hydroxy-2',3,4',5'-tetramethoxy-5-methylbiphenyl 1ab*<sup>[2]</sup>

<sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>): δ = 6.83 (s, 1H), 6.69 (d, *J* = 2.0 Hz, 1H), 6.67 (dd, *J* = 2.0, 0.9 Hz, 1H), 6.63 (s, 1H), 5.95 (s, 1H), 3.92 (s, 3H), 3.89 (s, 3H), 3.84 (s, 3H), 3.78 (s, 3H), 2.31 (d, *J* = 0.7 Hz, 3H). <sup>13</sup>C NMR (101 MHz, CDCl<sub>3</sub>): δ = 150.33, 149.25, 147.40, 143.57, 140.86, 129.20, 125.16, 123.37, 118.56, 115.01, 111.21, 98.46, 57.26, 56.44, 56.12, 55.98, 21.13.

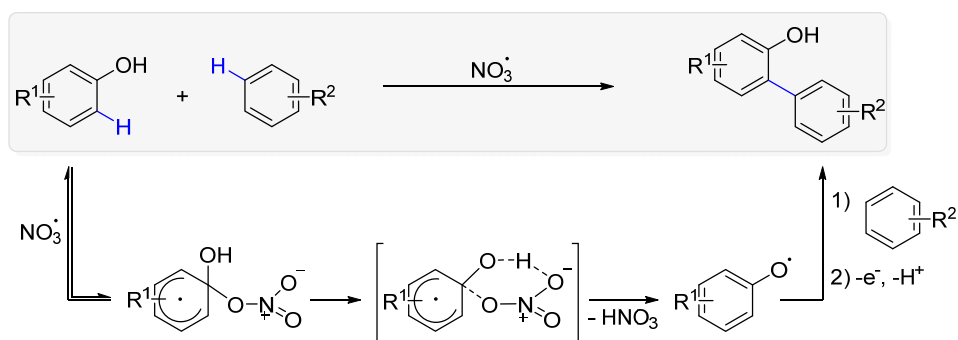
### *2,2',4,4',5,5'-Hexamethoxy-1,1'-biphenyl 1bb*<sup>[2]</sup>

<sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>): δ = 6.82 (s, 2H), 6.63 (s, 2H), 3.93 (s, 6H), 3.84 (s, 6H), 3.75 (s, 6H). <sup>13</sup>C NMR (101 MHz, CDCl<sub>3</sub>): δ = 151.25, 148.81, 142.91, 118.95, 115.35, 98.41, 56.90, 56.55, 56.12.

### Detailed Mechanism for the Activation of Phenols by $\text{NO}_3^\cdot$

The activation of phenols by  $\text{NO}_3^\cdot$  is supposed to proceed via an overall  $\text{H}^\cdot$ -abstraction mechanism or through oxidative electron transfer followed by deprotonation.

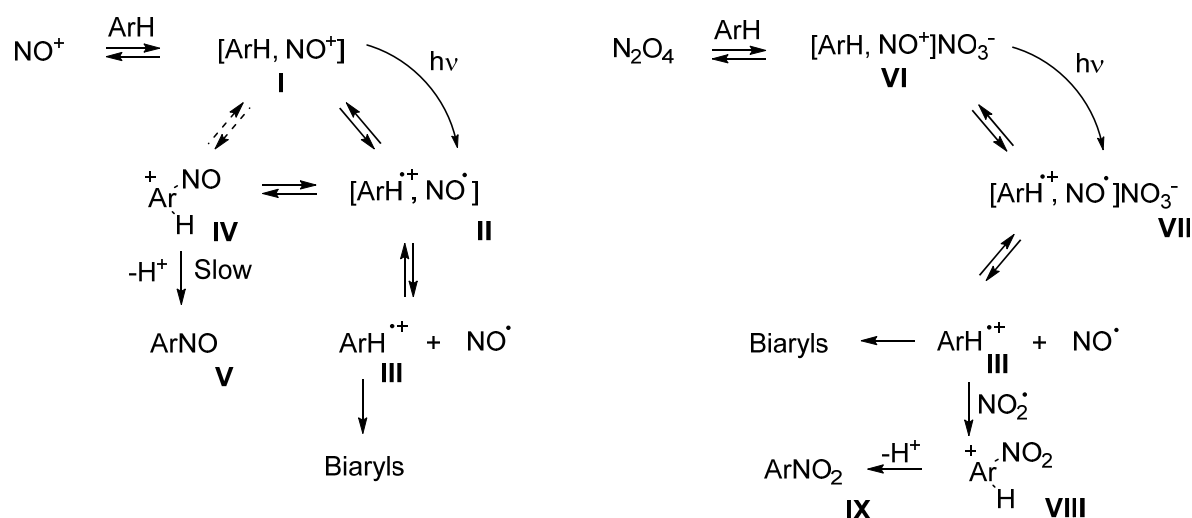
Scheme S1 outlined the  $\text{H}^\cdot$ -abstraction mechanism. After a reversible addition of  $\text{NO}_3^\cdot$  to the ipso position of phenols, a six-center rearrangement occurred providing  $\text{HNO}_3$  and a phenoxy radical. The electrophilic radical can be trapped by electron-rich arenes to form unsymmetrical biaryls after another oxidation/deprotonation step.<sup>[3]</sup>



**Scheme S1.** Mechanistic working proposal for the activation of phenols by  $\text{NO}_3^\cdot$  and the subsequent coupling with arenes.<sup>[3]</sup>

## Detailed Mechanism of the NO<sup>+</sup>-mediated Arene Oxidation

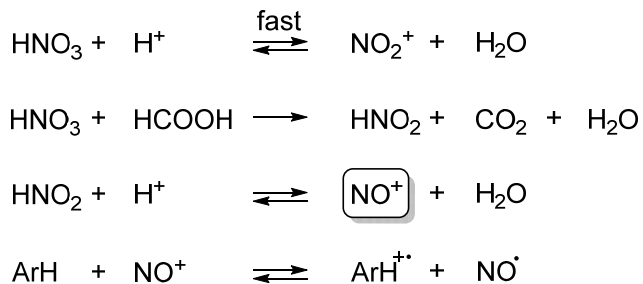
Literature reported mechanistic studies on the oxidation of arenes by NO<sup>+</sup> showed that the two components interact via the formation of a CT complex.<sup>[4]</sup> The CT complex **I** is in a thermal equilibrium with the corresponding complex **II** containing the arene radical cation and NO<sup>•</sup>. If the aromatic system is electron-rich, an electron transfer takes place. However, the electron transfer can also be initiated photoinduced by excitation of the respective CT band at low temperatures.<sup>[4]</sup> Competing reactions of the complex **II** are back electron transfer or the formation of the Wheland intermediate **IV** leading after deprotonation to nitroso products **V**. Dissociation of the complex **II** results in the free radical cation **III**, which can undergo further reactions dependent on the conditions, e.g. the desired cross-coupling reaction. Starting from the N<sub>2</sub>O<sub>4</sub> a substrate promoted ionization of the dimer provides the CT complex **VI**. In analogy to the complex **I** the electron transfer to the complex of the corresponding radical pair **VII** can proceed thermal or photoinduced. The free radical cation **III** can undergo cross-coupling to biaryls or can form nitro compounds **IX** by addition of NO<sub>2</sub><sup>•</sup> via the Wheland intermediate **VIII**.<sup>[4a]</sup>



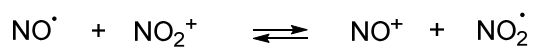
**Scheme S2.** Reaction pathways of nitrosonium ions or nitrosyl nitrate with aromatic compounds.<sup>[4]</sup>

### Alternative Pathways for the *in situ* NO<sup>+</sup> Formation and Regeneration

Scheme S3 depicts an alternative formulation of the possible equilibria involved in the *in situ* NO<sup>+</sup> generation. The nitronium ion NO<sub>2</sub><sup>+</sup> ( $E(\text{NO}_2^+/\text{NO}_2^\bullet) = 1.31 \text{ V vs. SCE in MeCN}$ ) is described in literature as a possible oxidant for regeneration of NO<sup>+</sup>. However, the mechanism of this oxidation step is more complicated and is simplified here for clarity.<sup>[4a]</sup>



**Regeneration:**



**Scheme S3.** Alternative pathways for the *in situ* generation of the active NO<sup>+</sup> species.<sup>[4a, 5]</sup>



## References

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