DOI: 10.1002/ejoc.201100909

Multiple Reaction Pathways between the Carbanions of α-Alkoxy-α-phenylacetonitrile and *o*-Chloronitrobenzene

Mieczysław Mąkosza*[a] and Daniel Sulikowski[a]

Dedicated to Professor V. N. Charushin on the occasion of his 60th birthday

Keywords: Carbanions / Nitroarenes / Reaction mechanisms / Vicarious substitution / Reactive intermediates / Oxidative substitution / S_NAr reaction

Carbanions of α-methoxy- and α-phenoxy-α-phenylacetonitriles undergo a variety of reactions with *o*-chloronitrobenzene by initial formation of σ^H adducts and slower formation of σ^{Cl} adducts. Reversible formation of σ^H adducts followed by their fast transformation results in the formation of four different products with high selectivity. Slower addition in a position occupied by a chlorine atom to form σ^{Cl} adducts results in a conventional S_NAr reaction. These five reaction pathways are efficiently controlled by the conditions and additional reagents.

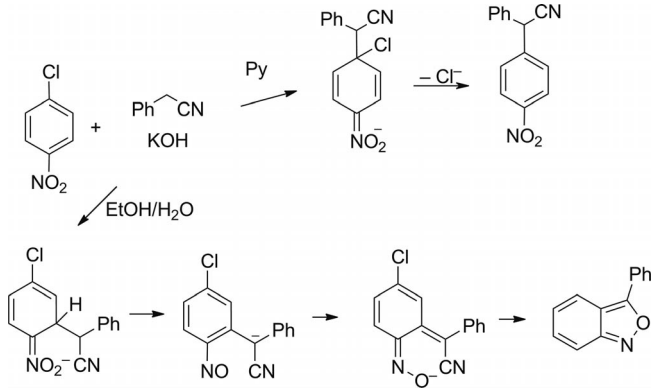
Introduction

The formation of two different products in a reaction between two reactants is a common situation. It is enough to mention the formation of isomers in electrophilic aromatic substitution, two products of *O*- and *C*-, *C*- and *C*-, or *C*- and *N*-alkylation of ambident anions, and 1,2- or 1,4-addition of Grignard reagents and carbanions to β-vinyl ketones. Much less frequent are cases when two reactants enter three different reactions and form three different products.

Here we would like to report a peculiar case where two reactants react along five different pathways to give five different products. Most importantly, we can control the course of the reaction by selecting conditions (temperature and solvent) and additional reagents, which make the reactions proceed with high selectivity.

The carbanion of α-phenylacetonitrile can react with *p*-chloronitrobenzene in two entirely different ways. In pyridine, a conventional S_NAr reaction with chlorine has been observed, whereas in aqueous ethanol, 3-phenylbenzisoxazole (anthranile) has been obtained as presented in Scheme 1.[1]

The results presented in Scheme 1 are explained as follows: both of the products were obtained by the addition of the α-phenylacetonitrile carbanion to *p*-chloronitrobenzene in the 4- or 2-position relative to the nitro group to form σ^{Cl} and σ^H adducts, respectively. The spontaneous departure of Cl^- anions from σ^{Cl} adducts resulted in the formation of S_NAr products, whereas σ^H adducts formed in protic media were initially converted into nitrosoarenes by the protonation/elimination of water. In strongly basic reaction media, deprotonation of the α-(nitrosoaryl)acetonitrile followed by intramolecular addition/elimination of the cyanide anion gave the anthranile.



Scheme 1. Reaction of *p*-chloronitrobenzene with the carbanion of α-phenylacetonitrile in pyridine and aqueous ethanol.

Following these observations, we have reported that the carbanion of α,α-diphenylacetonitrile generated under various conditions can react with *o*-chloronitrobenzene in three different ways. When the carbanion was generated in dimethyl sulfoxide (DMSO), an S_NAr reaction of chlorine took place; in methanol, nitrone was generated as a result of initial formation of the nitroso compound, whereas in benzene single-electron transfer (SET) took place to produce tetraphenylsuccinonitrile and azoxybenzene.[2] The two first reactions proceeded by the formation of anionic σ^X and σ^H adducts, respectively.

[a] Institute of Organic Chemistry, Polish Academy of Sciences, Ul.Kasprzaka 44/52, 01-224 Warsaw, Poland
Fax: +48-22-632-66-81
E-mail: icho-s@icho.edu.pl

Based on these results, we formulated the hypothesis that the addition of carbanions and other nucleophiles to nitroarenes in the positions occupied by a hydrogen atom is a fast and reversible process, whereas slower addition in positions occupied by a halogen atom (X) is essentially irreversible because of the facile departure of the X^- anion from the σ^X adducts.[3] Furthermore, many ways to convert the σ^H adducts into products of nucleophilic substitution of a hydrogen atom have been developed so that this reaction has become a general, versatile process.[3,4] The most important of these conversions are: oxidation of σ^H adducts with external oxidants,[3b,5,6] vicarious nucleophilic substitution when the carbanions contain a leaving group such as Cl or RO,[3,6,7] and conversion of the σ^H adducts into nitrosoarenes.[3b,6]

Relationships between the rates of conventional nucleophilic substitution of halogen S_NAr reactions and nucleophilic substitution of a hydrogen atom in halonitrobenzenes and unambiguous proof that the substitution of a hydrogen atom is the main process have been presented in our recent reviews.[8]

In this paper we report that the carbanions of α-methoxy- and α-phenoxy-α-phenylacetonitriles (**1** and **2**, respectively) can react with *o*-chloronitrobenzene (**3**) along five different pathways to give five different products, four of which are products of the substitution of a hydrogen atom. The course of the reaction can be controlled by the conditions and additional reagents to ensure high selectivity and high yields of the products.

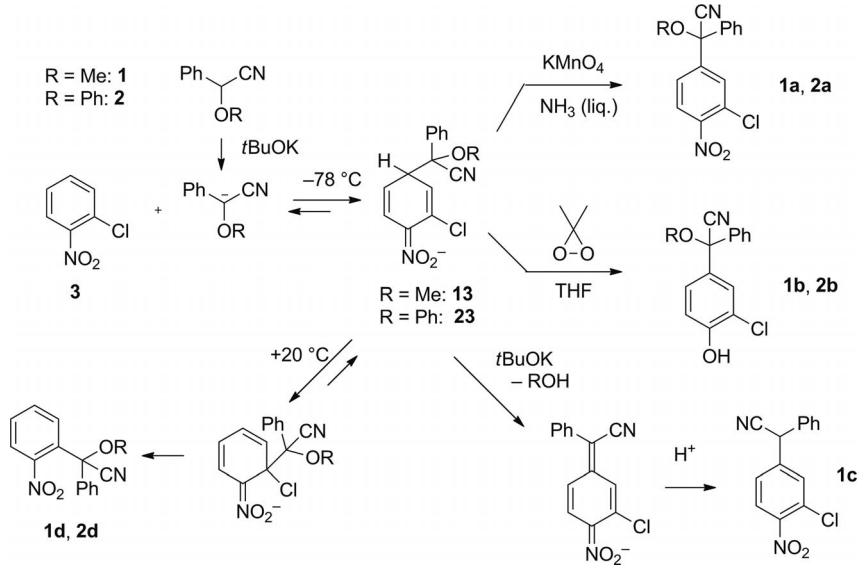
Results and Discussion

According to the general pathway of reactions between carbanions and halonitroarenes, the initial, fast process is addition in the *ortho* or *para* position to the nitro group occupied by a hydrogen atom to form σ^H adducts.[3,8] The addition of sterically demanding carbanions of **1** and **2** to **3** proceeded preferentially in the *para* position.[9] The addition is a reversible process, however, and – thanks to the high nucleophilicity of these carbanions and entropy effects – it proceeds to completion at low temperature. Thus, when equimolar mixtures of **1** or **2** with **3** in tetrahydrofuran (THF)/*N*,*N*-dimethylformamide (DMF) at –78 °C were treated with an equimolar amount of *t*BuOK, the corresponding σ^H adducts **13** and **23** were formed quantitatively. The absence of free carbanions in such mixtures was confirmed by independent experiments.[9a]

The addition of oxidants to solutions of the σ^H adducts produced this way resulted in the formation of products from the oxidative substitution of a hydrogen atom, **1a** and **2a**. Oxidation of the σ^H adducts with 2,3-dichloro-5,6-dicyano-1,4-benzoquinone, commonly used for this purpose, was moderately effective with yields of 65 and 10% for **1a** and **2a**, respectively. Oxidation with potassium permanganate was much more efficient and gave yields of 83 and 60% for **1a** and **2a**, respectively. In these cases, powdered $KMnO_4$ was added to the solution of the σ^H adduct in THF/DMF followed by addition of liquid ammonia to dissolve the inorganic salt. Alternatively, the addition of $\mathbf{1}^-$ and $\mathbf{2}^-$ to **3** and the oxidation can be executed in liquid ammonia as reported earlier.[9]

Oxidation of the σ^H adducts of the carbanions of α-phenylalkanenitriles to nitroarenes with dimethyldioxirane (DMD) proceeded at the negatively charged nitro group to give substituted phenols.[10] Oxidation of the σ^H adducts **13** and **23** with DMD proceeded similarly to give 3-chloro-4-hydroxyphenyl derivatives of **1** and **2**, **1b** and **2b**, respectively. The reactions are presented in Scheme 2.

The carbanions of **1** and **2** contain a leaving group (methoxy and phenoxy, respectively) at the nucleophilic center; thus, treatment of the σ^H adducts with a strong base should result in β-elimination of methanol or phenol to give



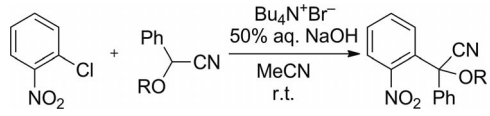
Scheme 2. Conversion of initial σ^H adducts of carbanions of **1** and **2** with **3**.

products of the vicarious substitution of a hydrogen atom (VNS).[3,6] Indeed, when **1** and **2** were treated with **3** in the presence of excess *t*BuOK (3 equiv.), the mixtures turned deep blue because of the formation of the nitrobenzylic carbanion of α-(3-chloro-4-nitrophenyl)acetonitrile (**1c**). Upon acidification, **1c** was isolated in high yield. Of course, in the reaction of both of these carbanions, which differ only in the leaving group present, the same product **1c** was obtained in excellent yields (99% starting from **2**, Scheme 2).

As mentioned above, the addition of carbanions in the positions occupied by a hydrogen atom to form σ^H adducts is a reversible process. Because of the high nucleophilicity of the carbanions of **1** and **2** and the entropy effect, at low temperatures their addition to **3** proceeded to completion. However, when solutions of the σ^H adducts **13** and **23** formed at low temperature were slowly warmed, dissociation of the σ^H adducts liberated free carbanions. These carbanions could enter slower addition in the position occupied by a chlorine atom to form σ^{Cl} adducts, which was followed by fast spontaneous dissociation of the carbon–chlorine bond to form products of a conventional S_NAr substitution reaction of a chlorine atom. Alternatively, the liberated carbanion could also act as a base, which promoted β-elimination of methanol or phenol from the σ^H adduct, so VNS took place. Indeed, when solutions of **13** and **23** formed in THF/DMF in the absence of excess of base at low temperature were slowly warmed to room temp., S_NAr products **1d** and **2d** were formed. As expected, base-induced β-elimination of phenol is much more facile than that of methanol; thus, warming of a solution of **23** also gave some of the VNS product **1c**. These results indicate unambiguously that the S_NAr of a halogen atom was the secondary reaction that proceeded when the initial σ^H adducts were not converted into products of the substitution of a hydrogen atom, and the conditions promoted their dissociation. Dissociation of the σ^H adduct and the subsequent S_NAr reaction by the slower formation of σ^{Cl} adducts led to **1d** and **2d** (Scheme 2).

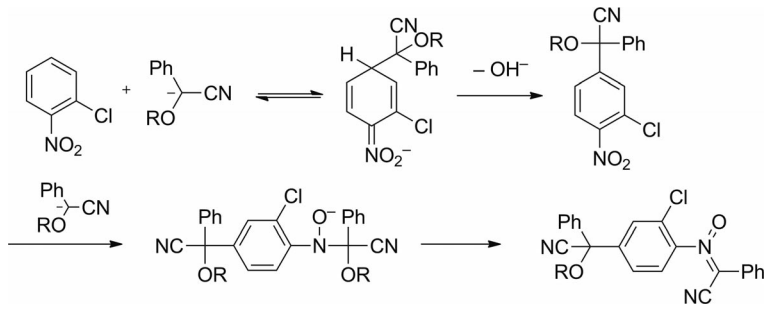
Under the conditions that ensure fast equilibration of the addition, in the absence of excessive base and oxidants, reactions of the carbanions of **1** and **2** with **3** proceeded exclusively by irreversible addition in the position occupied by a chlorine atom, which was followed by the fast, spontaneous departure of the chloride anion and formation of S_NAr products **1d** and **2d**. These criteria are met by phase-transfer catalysis (PTC) conditions, i.e. the generation of carbanions in a two-phase system by the action of concentrated aqueous NaOH with tetraalkylammonium bromide as the catalyst on the carbanion precursors located in the organic phase.[11] Low concentration of the carbanions in the organic phase, which cannot exceed the concentration of the catalyst, ensures that, at room temp., the initially formed σ^H adducts dissociate rapidly, so slower formation of the σ^{Cl} adduct occured, which was followed by the fast departure of Cl^- and resulted in an S_NAr reaction. The effectiveness of PTC conditions for the nitroarylation of carbanions has been demonstrated.[2,12]

Indeed, when equimolar amounts of **1** or **2** with **3** were dissolved in a small volume of acetonitrile and stirred with an excess of 50% aqueous NaOH and 5 mol-% tetrabutylammonium bromide (TBAB), a fast S_NAr reaction of the chlorine atom took place to give **1d** (85%) and **2d** (72%), respectively (Scheme 3). In the latter case, **1c** (5%), the product of the VNS reaction, was also formed, because elimination of phenol from the σ^H adduct is a relatively fast process. Since **1c** exists in the reaction mixture as a carbanion that forms a lipophilic ion pair with the TBA cation, the VNS side reaction inhibits the catalytic process.[12]



Scheme 3. Reactions of the carbanions of **1** and **2** with **3** under PTC conditions.

As mentioned above, σ^H adducts of carbanions with nitroarenes can be transformed into nitrosoarenes in protic media by protonation/elimination according to the intramolecular redox stoichiometry.[1,2,6] The nitroso group is a very active electrophile; hence, nitrosoarenes cannot usually be isolated, because they enter further reactions with carbanions or basic agents present in the reaction mixture. Thus, when **1** or **2** and **3** were treated with *t*BuOK in *tert*-butyl alcohol, the final products were nitrones **1e** and **2e**, formed in reasonable yields of 21 and 65%, respectively. The formation of **1e** and **2e** proceeds according to the pathway shown



Scheme 4. Reaction of carbanions **1** and **2** with **3** in protic media.

in Scheme 4. The initially formed σ^H adducts were converted into nitrosoarene by protonation/elimination. Addition of the second carbanion to the nitroso group and subsequent elimination of methoxide or phenoxide anions resulted in the formation of nitrones **1e** and **2e**, respectively.

Thus, so far we have shown that, by variation of conditions and additional reagents, the reaction of the carbanions of **1** and **2** with **3** can proceed along five different pathways to give five different products: **1a**, **1b**, **1c**, **1d**, **1e**, **2a**, **2b**, **1c**, **2d**, and **2e**, respectively. These five pathways are: two variants of oxidative nucleophilic substitution of a hydrogen atom resulting in the formation of substituted nitroarenes and substituted phenols, VNS, conversion of σ^H adducts into nitrosoarenes followed by their reaction with carbanions, and conventional nucleophilic substitution of a chlorine atom, S_NAr.

The first four of these pathways were initiated by fast, reversible addition of the carbanions of **1** and **2** to **3** in the *para* position to form the σ^H adducts **13** and **23**, which subsequently entered four different reactions to form four different products. As the conversion of the σ^H adducts into these products is faster than dissociation, one can consider that these reactions are kinetically controlled. The fifth pathway, the conventional S_NAr reaction of a chlorine atom, which requires equilibration of the addition process, is a secondary, thermodynamically controlled process.[8]

It is well known that nitroarenes are strong electron acceptors, whereas carbanions are good electron donors; thus, SET between these reactants proceeded easily to form radical and nitroaromatic radical anions,[4c,13] which combined to form σ adducts. In fact the SET mechanism has been proposed as a pathway for the formation of σ adducts, and such a concept has often been abused.[14] We have already shown that the formation of σ^H adducts, as a pathway for VNS, proceeds as a direct addition and not by a two-step SET process.[15] However, when direct addition was hindered by conditions, SET could proceed, which led to other reactions. Thus, we have shown previously[2] that the sodium α,α-diphenylacetonitrile carbanion in DMSO at room temperature replaces the chlorine atom in *o*-chloronitrobenzene, whereas in benzene, when the carbanions exist as aggregates and their nucleophilicity was decreased, the reaction resulted in dimerization of the carbanion and formation of azoxybenzene.[2] Apparently, the diphenylcyanomethyl radical produced by SET reacted with the carbanion to form the radical anion of tetraphenylsuccinonitrile, which was subsequently oxidized by the nitroarene to the succinonitrile.

We expected that under similar conditions the carbanions of **1** or **2** should dimerize. However, mixing of sodium or lithium salts of the carbanions of **1** or **2** with **3** in benzene or cyclohexane, conditions that usually ensure high aggregation, did not result in dimerization. Even warming such mixtures for a few hours did not result in the formation of definite products, and in particular no dimers of **1** or **2** were detected. Upon acidic quenching of such reaction mixtures, the majority of the starting materials were recovered. This was somewhat surprising, because SET from the carbanions of **1** and **2** to **3** should be facile as the alkoxycyano radicals produced should enjoy specific capto-dative stabilization.[16]

Conclusions

The results presented lead to two major conclusions:

1. Reactions of carbanions with nitroarenes can proceed in a variety of ways and thus offer a valuable tool for organic synthesis, albeit with some challenging mechanistic questions.

2. Once again, it was shown that the S_NAr nucleophilic substitution of the halogen atom in halonitrobenzenes, which proceeds via σ^X adducts is a slow, secondary process, whereas the nucleophilic substitution of a hydrogen atom, which proceeds by fast conversion of the σ^H adducts formed initially, is the primary process.

Experimental Section

General Remarks: ^1H and ^{13}C NMR spectra were recorded with Varian 500 MHz or 200 MHz spectrometers in $CDCl_3$ with TMS as a standard. Chemical shifts are given in ppm relative to TMS, and coupling constants (*J*) are given in Hertz (Hz). EI mass spectra were recorded with an AMD 604 Inectra GmbH spectrometer at 70 eV, and ESI mass spectra were recorded with a Mariner™ spectrometer. THF was distilled from potassium/benzophenone ketyl, and DMF was distilled from CaH_2. Silica gel Merck 60 (230–400 mesh) was used for column chromatography. α-Methoxy- and α-phenoxy-α-phenylacetonitriles **1** and **2** were obtained from α-phenyl-α-tosyloxyacetonitrile by solvolysis in methanol or reaction with sodium phenoxide, respectively.[17]

Oxidative Nucleophilic Substitution of H in 3 with the Carbanion of 1 or 2: To a solution of *o*-chloronitrobenzene (**3**) (0.5 mmol, 74 mg) and α-alkoxy-α-phenylacetonitrile **1** or **2** (0.5 mmol) in THF/DMF (6 mL, 2:1, v/v) at –78 °C was added a solution of *t*BuOK in THF (0.52 mmol, 0.52 mL, 1 M) over 5 min, and the resulting mixture was stirred at this temperature for further 15 min. After this time, either (a) or (b) was followed.

(a) Potassium permanganate (158 mg, 1.0 mmol) was added followed by liquid ammonia (ca. 10 mL). After 2 min, the reaction mixture was quenched by the addition of solid ammonium chloride (ca. 500 mg). The reaction mixture was allowed to reach room temperature and, after the addition of water (10 mL), extracted with ethyl acetate. The organic phase was dried, the solvents were evaporated, and the residue was purified by column chromatography (toluene) to give **1a** or **2a**.

(b) A solution of DMD (10 mL, 0.05 M) in acetone was added and the mixture allowed to reach room temperature. Sodium sulfite (approx. 50 mg) was added to destroy the excess DMD. The solvents were evaporated under reduced pressure, and the residue was purified as described above to give **1b** or **2b**.

Vicarious Nucleophilic Substitution of H in 3 with the Carbanion of 1 or 2: To a mixture of THF/DMF (6 mL, 2:1, v/v) cooled to –78 °C was added a solution of *t*BuOK (2.0 mmol, 2.0 mL, 1 M) followed by a mixture of **3** (0.5 mmol, 74 mg) and **1** or **2** (0.5 mmol) in THF (1 mL), which was added dropwise over 5 min. After stir-

ring for 10 min, the reaction mixture was quenched at –78 °C by addition of 10% aq. HCl (10 mL) and left to reach room temperature. The workup was performed as described above. Product **1c** was obtained as a colorless oil that solidified. Analytical data are identical to those reported.[18]

S_NAr Substitution of Cl in 3 with the Carbanion of 1 or 2 under PTC Conditions: To a solution of **3** (0.5 mmol, 74 mg), **1** or **2** (0.5 mmol), and TBAB (16 mg, 0.05 mmol) in acetonitrile (0.5 mL) was added a 50% aqueous solution of NaOH in water (2 mL). The resulting mixture was stirred vigorously at room temperature for 15 min, followed by addition of water (10 mL). The mixture was extracted with dichloromethane, and the organic phase was dried, concentrated, and the products were purified by column chromatography. Products **1d** or **2d** were obtained as yellow oils.

Nitrone Formation in the Reaction of 3 with the Carbanions of 1 or 2 in *tert*-Butyl Alcohol: To a solution of *t*BuOK (56 mg, 0.5 mmol) in *tert*-butyl alcohol (4 mL) was added a solution of **3** (0.5 mmol, 74 mg) and **1** or **2** (1.0 mmol) in *tert*-butyl alcohol (1.0 mL). The resulting mixture was stirred at 65 °C for 3 h (with **2**) or 24 h (with **1**). After cooling to room temperature, 10% aq. HCl (10 mL) was added, and the workup was performed as described above. Products **1a** and **2e** were obtained as orange solids.

Analytical Data for New Compounds

α-(3-Chloro-4-nitrophenyl)-α-methoxy-α-phenylacetonitrile (1a): Yield: 125 mg, 83%; oil. IR (film, CH_2Cl_2): $\tilde{\nu}$ = 3102, 2938, 2228, 1532, 1349 cm^{-1}. ^1H NMR (500 MHz, $CDCl_3$): δ = 7.86 (d, J = 8.0 Hz, 1 H), 7.49 (d, J = 2.0 Hz, 1 H), 7.51 (d, J = 2 Hz, 1 H), 7.50–7.42 (m, 5 H), 3.45 (s, 3 H) ppm. ^{13}C NMR (125 MHz, $CDCl_3$): δ = 147.8, 145.0, 136.4, 130.0, 129.6, 129.4, 127.7, 126.4, 125.9, 125.6, 116.8, 81.3, 54.5 ppm. EI-MS: *m*/*z* (%) = 302 (20) $[M]^+$. $C_{15}H_{11}ClN_2O_3$ (302.72): calcd. C 59.52, H 3.66, N 9.25; found C 59.70, H 3.60, N 9.10.

α-(3-Chloro-4-nitrophenyl)-α-phenoxy-α-phenylacetonitrile (2a): Yield: 109 mg, 60%; solidifying oil. IR (film, CH_2Cl_2): $\tilde{\nu}$ = 3101, 3039, 2229, 1532, 1349, 1209 cm^{-1}. ^1H NMR (500 MHz, $CDCl_3$): δ = 7.90 (d, J = 8.5 Hz, 1 H), 7.85 (d, J = 1.0 Hz, 1 H), 7.62 (dd, J = 8.5, 2.0 Hz 1 H), 7.54–7.51 (m, 2 H), 7.43–7.40 (m, 3 H), 7.28–7.20 (m, 3 H), 6.95–6.90 (m, 2 H) ppm. ^{13}C NMR (125 MHz, $CDCl_3$): δ = 153.8, 147.9, 144.9, 136.7, 133.7, 130.1, 130.0, 129.7, 129.6, 129.3, 126.6, 126.0, 125.5, 120.0, 117.0, 80.6 ppm. EI-MS: *m*/*z* (%) = 364 (6) $[M]^+$. $C_{20}H_{13}ClN_2O_3$ (364.79): calcd. C 65.85, H 3.59, N 7.68; found C 66.01, H 4.20, N 7.60.

α-(3-Chloro-4-hydroxyphenyl)-α-methoxy-α-phenylacetonitrile (1b): Yield: 69 mg, 51%; oil. IR (film, CH_2Cl_2): $\tilde{\nu}$ = 3384 (br), 3064, 2239, 1605, 1498, 1450 cm^{-1}. ^1H NMR (500 MHz, $CDCl_3$): δ = 7.47–7.43 (m, 4 H), 7.40–7.35 (m, 4 H), 5.65 (br. s, 1 H), 3.39 (s, 3 H) ppm. ^{13}C NMR (125 MHz, $CDCl_3$): δ = 151.9, 138.1, 132.3, 129.3, 128.9, 128.8, 127.2, 126.9, 126.5, 117.9, 116.4, 81.4, 54.2 ppm. EI-MS: *m*/*z* (%) = 273 (31) $[M]^+$. $C_{15}H_{12}ClNO_2$ (273.72): calcd. C 65.82, H 4.42, N 5.12; found C 65.50, H 4.21, N 5.51.

α-(3-Chloro-4-hydroxyphenyl)-α-phenoxy-α-phenylacetonitrile (2b): Yield: 23 mg, 13%; solidifying oil. IR (film, CH_2Cl_2): $\tilde{\nu}$ = 3380, 3063, 2243, 1590, 1532 cm^{-1}. ^1H NMR (200 MHz, $CDCl_3$): δ = 7.91–7.83 (m, 2 H), 7.61–7.42 (m, 6 H), 7.32–7.21 (m, 3 H), 7.12–7.06 (m, 2 H), 5.80 (br. s, 1 H) ppm. ^{13}C NMR (125 MHz, $CDCl_3$): δ = 156.3, 144.7, 141.6, 136.6, 133.3, 130.0, 129.9, 129.6, 129.3, 129.2, 127.2, 126.5, 123.3, 121.6, 116.3, 80.6 ppm. EI-MS: *m*/*z* (%) = 355 (2) $[M]^+$. $C_{20}H_{14}ClNO_2$ (335.79): calcd. C 71.54, H 4.20, N 4.17; found C 71.44, H 4.22, N 4.00.

α-Methoxy-α-(2-nitrophenyl)-α-phenylacetonitrile (1d): Yield: 115 mg, 86%; yellowish oil. IR (film, CH_2Cl_2): $\tilde{\nu}$ = 3094, 2937, 2230, 1533, 1354 cm^{-1}. ^1H NMR (500 MHz, $CDCl_3$): δ = 7.88 (dd, J = 8.0, 1.0 Hz, 1 H), 7.62–7.61 (m, 1 H), 7.53–7.50 (m, 2 H), 7.45–7.40 (m, 5 H), 3.34 (s, 3 H) ppm. ^{13}C NMR (125 MHz, $CDCl_3$): δ = 148.9, 143.5, 137.5, 135.6, 129.8, 129.3, 128.9, 127.5, 127.4, 125.2, 115.2, 81.7, 53.9 ppm. EI-MS: *m*/*z* (%) = 268 (5) $[M]^+$. $C_{15}H_{12}N_2O_3$ (268.27): calcd. C 67.16, H 4.51, N 10.44; found C 67.10, H 4.80, N 10.20.

α-(2-Nitrophenyl)-α-phenoxy-α-phenylacetonitrile (2d): Yield: 119 mg, 72%; yellowish oil. IR (film, CH_2Cl_2): $\tilde{\nu}$ = 3095, 3041, 2230, 1532, 1353, 1217 cm^{-1}. ^1H NMR (500 MHz, $CDCl_3$): δ = 8.2 (d, J = 7.9 Hz, 1 H), 7.87 (dd, J = 7.5, 1.0 Hz, 1 H), 7.61–7.59 (m, 2 H), 7.47–7.35 (m, 7 H), 7.25–7.10 (m, 3 H) ppm. ^{13}C NMR (125 MHz, $CDCl_3$): δ = 165.1, 156.4, 151.0, 133.6, 132.8, 130.1, 129.9, 129.5, 127.5, 127.3, 126.3, 123.4, 116.4, 80.1 ppm. EI-MS: *m*/*z* (%) = 330 (3) $[M]^+$. $C_{20}H_{14}N_2O_3$ (330.34): calcd. C 72.72, H 4.27, N 8.48; found C 72.90, H 4.50, N 8.40.

2-Chloro-4-[cyano(methoxy)(phenyl)methyl]-*N*-[cyano(phenyl)methylene]aniline *N*-Oxide (1e): Yield: 38 mg, 21%; solidifying oil. IR (film, CH_2Cl_2): $\tilde{\nu}$ = 3102, 3042, 2231, 2201, 1534, 1349, 1210 cm^{-1}. ^1H NMR (500 MHz, $CDCl_3$): δ = 8.14–8.10 (m, 3 H), 7.61 (m, 1 H), 7.50–7.45 (m, 4 H), 7.38–7.35 (m, 2 H), 7.43–7.40 (m, 3 H), 7.28–7.20 (m, 3 H), 6.95–6.90 (m, 2 H) ppm. ^{13}C NMR (125 MHz, $CDCl_3$): δ = 171.9, 143.6, 138.6, 133.8, 130.2, 129.9, 129.1, 128.7, 128.6, 128.5, 127.7, 127.1, 126.5, 126.2, 119.1, 118.1, 115.5, 81.8, 54.1 ppm. EI-MS: *m*/*z* (%) = 401 (2) $[M]^+$. $C_{23}H_{16}ClN_3O_2$ (401.85): calcd. C 68.74, H 4.01, N 10.46; found C 68.86, H 4.11, N 10.01.

2-Chloro-4-[cyano(phenoxy)(phenyl)methyl]-*N*-[cyano(phenyl)methylene]aniline *N*-Oxide (2e): Yield: 38 mg, 65%; solidifying oil. IR (film, CH_2Cl_2): $\tilde{\nu}$ = 3103, 3039, 2233, 2209, 1530, 1209 cm^{-1}. ^1H NMR (200 MHz, $CDCl_3$): δ = 8.14–8.10 (m, 2 H), 7.93–7.90 (m, 1 H), 7.62–7.58 (m, 2 H), 7.58–7.31 (m, 6 H), 7.31–7.19 (m, 4 H), 6.98–6.89 (m, 1 H), 6.86–6.60 (m, 2 H) ppm. ^{13}C NMR (125 MHz, $CDCl_3$): δ = 171.4, 155.6, 137.7, 134.4, 133.7, 131.1, 130.2, 130.1, 130.0, 129.8, 129.6, 129.3, 129.0, 128.7, 128.6, 128.4, 128.2, 127.6, 120.6, 115.3, 118.9, 81.7 ppm. EI-MS: *m*/*z* (%) = 463 (3) $[M]^+$. $C_{28}H_{18}ClN_3O_2$ (463.92): calcd. C 72.49, H 3.91, N 9.06; found C 72.61, H 4.20, N 9.43.

[1] R. B. Davis, L. C. Pizzini, *J. Org. Chem.* **1960**, *25*, 1884.
[2] M. Mąkosza, M. Jagusztyn-Grochowska, M. Ludwikow, M. Jawdosiuk, *Tetrahedron* **1974**, *30*, 3723.
[3] a) M. Mąkosza, J. Winiarski, *Acc. Chem. Res.* **1987**, *20*, 282; b) M. Mąkosza, *Russ. Chem. Bull.* **1996**, *45*, 491.
[4] a) V. A. Charushin, O. N. Chupakhin, *Mendeleev Commun.* **2007**, *15*, 249; b) O. N. Chupakhin, V. N. Charushin, H. C. van der Plas, *Nucleophilic Aromatic Substitution of Hydrogen*, Academic Press, San Diego, CA, **1994**; c) F. Terrier, *Nucleophilic Aromatic Displacement*, VCH, Weinheim, **1991**.
[5] M. Mąkosza, M. Paszewski, *Pol. J. Chem.* **2005**, *79*, 163.
[6] M. Mąkosza, K. Wojciechowski, *Chem. Rev.* **2004**, *104*, 2631.
[7] M. Mąkosza, A. Kwast, *J. Phys. Org. Chem.* **1998**, *11*, 341.
[8] a) M. Mąkosza, *Chem. Soc. Rev.* **2010**, *39*, 2855; b) M. Mąkosza, *Synthesis* **2011**, 2341.
[9] a) M. Mąkosza, K. Staliński, *Chem. Eur. J.* **1997**, *3*, 2025; b) M. Mąkosza, K. Staliński, *Tetrahedron Lett.* **1998**, *39*, 3575.
[10] a) W. Adam, M. Mąkosza, K. Staliński, C. G. Zhao, *J. Org. Chem.* **1998**, *63*, 4390; b) W. Adam, M. Mąkosza, C.-G. Zhao, M. Surowiec, *J. Org. Chem.* **2000**, *65*, 1099.
[11] a) M. Mąkosza, *Pure Appl. Chem.* **1975**, *43*, 439; b) M. Mąkosza, M. Fedoryński, *Catal. Rev.* **2003**, *45*, 321.
[12] M. Mąkosza, *Tetrahedron Lett.* **1969**, *10*, 673.
[13] a) G. A. Russel, E. G. Janzen, E. T. Strom, *J. Am. Chem. Soc.* **1964**, *86*, 1807; b) I. I. Bilkis, S. M. Shein, *Tetrahedron* **1975**, *31*, 969.

[14] X.-M. Zhang, D.-L. Young, Y.-C. Liu, *J. Org. Chem.* **1993**, *58*, 224 and rebuttal, M. Mąkosza, R. Podraza, A. Kwast, *J. Org. Chem.* **1994**, *59*, 6796.
[15] M. Mąkosza, A. Kwast, *Eur. J. Org. Chem.* **2004**, 2125.
[16] L. Stella, Z. Janousek, R. Merenyi, H. G. Viehe, *Angew. Chem.* **1978**, *90*, 741; *Angew. Chem. Int. Ed. Engl.* **1978**, *17*, 691.
[17] M. Mąkosza, T. Goetzen, *Rocz. Chem.* **1972**, *46*, 1059.
[18] M. Mąkosza, J. Winiarski, *J. Org. Chem.* **1984**, *49*, 1494.
Received: June 22, 2011
Published Online: September 27, 2011

