# Mechanistic Aspects of Iron-Catalyzed Allylic Amination

### Mogens Johannsen and Karl Anker Jørgensen\*

Department of Chemistry, Aarhus University, DK-8000 Aarhus C, Denmark

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#### Introduction

The use of metals for the functionalization of hydrocarbons is of fundamental interest and importance in chemistry. The introduction of heteroatoms, such as oxygen and nitrogen atoms, in the allylic position leads to compounds of utmost importance in organic chemistry. A variety of methods are available for allylic oxidation. of alkenes leading to allylic alcohols,<sup>1</sup> whereas only few procedures are known for the preparation of allylic amines from insertion of a nitrogen fragment into (in principle) an allylic C-H bond.<sup>2</sup> Stoichiometric processes using imido compounds (RN=X=NR,  $X = S^{2a,b,\bar{j}}$ ,  $Se^{2c}$ ) or molybdenum oxaziridines<sup>2d,e</sup> have been used with moderate success. However, very recently two transition metalcatalyzed reactions have been presented for catalytic allylic amination using either molybdenum<sup>2f</sup> or iron<sup>2g,i</sup> complexes as the catalysts and N-phenylhydroxylamine as the nitrogen fragment donor (reaction 1).

$$\checkmark + Ph-NHOH \xrightarrow{H}_{ML_n} \swarrow^{N}_{Ph} (1)$$

The iron-catalyzed allylic amination reaction has been shown to proceed well, especially for 1,1-disubstituted and 1,2-disubstituted alkenes, by applying iron phthalocyanine (Fe<sup>II</sup>Pc)<sup>2g</sup> or a combination of Fe<sup>II</sup> and Fe<sup>III</sup> salts<sup>2i</sup> as the catalyst. When the iron-catalyzed allylic amination reaction is compared with the similar molybdenum-catalyzed reaction, it appears that the former probably has the best catalytic properties, both in terms of yield of the allylic amine and in minimizing the amount of byproducts produced in the reaction.<sup>2e-i</sup> In the case of the molybdenum-catalyzed reaction, there is an indication that a molybdenum oxaziridine is involved at a certain stage of the reaction path,<sup>2d-f,h</sup> followed by a dissociation forming nitrosobenzene and a molybdenum-(IV) complex.<sup>2h</sup> The nitrosobenzene formed then reacts in an ene reaction with the alkene to produce an

*N*-alkylhydroxylamine, which is reduced by the molybdenum(IV) complex to the allylic amine and a molybdenum(VI) complex, thus completing the catalytic cycle.<sup>2h</sup> For the Fe<sup>II</sup>Pc-catalyzed allylic amination reaction our initial efforts did not give any significant clue about the mechanism for the reaction,<sup>2g</sup> and in later studies of the Fe<sup>II</sup> and Fe<sup>III</sup> salt catalyzed reaction it was postulated that free nitrosobenzene was not an intermediate.<sup>2i</sup>

To obtain some information about the mechanism of the Fe<sup>II</sup>Pc-catalyzed allylic amination, a series of experiments have been performed, and in this paper we will try to address the following questions: (i) what is the role of the catalyst, (ii) is the nitrogen fragment transferred via the metal (is it an on- or off-metal reaction), (iii) what is the nature of the nitrogen fragment transferred, and (iv) what is the mechanism for the reaction.

## **Results and Discussion**

Several mechanisms can account for the formation of the allylic amines in this iron-catalyzed reaction using N-phenylhydroxylamine as the nitrogen fragment donor, but the mechanism we postulate for the reaction is depicted in Scheme 1.

The first step in the catalytic cycle is proposed to be the formation of nitrosobenzene 3 from N-phenylhydroxylamine (7) by either (i) an iron-catalyzed disproportionation reaction of N-phenylhydroxylamine to nitrosobenzene and aniline 8a or (ii) an oxidation of N-phenylhydroxylamine to nitrosobenzene by **6** and in the case of (i) followed by an oxidation of aniline to a species which can enter the catalytic cycle. The next step is proposed to be an ene reaction of the alkene **2** with nitrosobenzene, giving the allylic hydroxylamine 4. The last step is suggested to involve Fe<sup>II</sup>Pc (5) reacting with the allylic hydroxylamine leading to a reduction of the allylic hydroxylamine to the allylic amine 1 and the concomitant formation of a high-valent iron phthalocyanine, which could be  $OFe^{IV}Pc$  (6). We will show that the mechanism for the iron-catalyzed allylic amination outlined in Scheme 1 is not an unlikely proposal. For these purposes we have performed a series of experiments.

1. Iron-Catalyzed Formation of Nitrosobenzene from N-Phenylhydroxylamine. The first step in the mechanism implies that nitrosobenzene can be formed by reaction of N-phenylhydroxylamine in the presence of a catalytic amount of Fe<sup>II</sup>Pc or other iron complexes. To evaluate if nitrosobenzene is formed by this reaction a series of trapping experiments have been performed as aromatic nitroso compounds are known to be very reactive in hetero Diels-Alder reactions.<sup>3</sup> Reaction of N-phenylhydroxylamine with 1,3-cyclohexadiene (9) in the presence of Fe<sup>II</sup>Pc (10 mol %) affords the hetero Diels-Alder product 10 in 60% yield after a 3 h reaction time at 60 °C (reaction 2), with small amounts of azoxybenzene (11) and aniline.<sup>4</sup> Without the presence of the catalyst the addition product is isolated in low

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<sup>(4)</sup> One attempt gave a 91% isolated yield of 10.



yield. Azoxybenzene is probably formed by reaction of N-phenylhydroxylamine with nitrosobenzene.<sup>5</sup>

Ph-NHOH + 
$$Fe(II)Pc$$
  $V_0^{Ph}$  (2)  
7 9 10

The formation of aniline can take place by a disproportionation reaction, *i.e.*, the function of  $Fe^{II}Pc$  is to catalyze the disproportionation of *N*-phenylhydroxy-lamine to nitrosobenzene and aniline.<sup>6</sup> The reason for the high yield of the hetero Diels-Alder product **10** (>50%) could be an autoxidation of *N*-phenylhydroxy-lamine, or aniline, catalyzed by the  $Fe^{II}Pc$  present.<sup>7</sup> These results indicate that the function of the iron complex is probably as (i) a disproportionation catalyst, (ii) a redox reagent, and/or (iii) an oxygen-transfer reagent, where *N*-phenylhydroxylamine, or molecular oxygen, can act as the terminal oxidant.

Aromatic hydroxylamines, such as N-phenylhydroxylamine, are not the only hydroxylamines that can be oxidized to the corresponding nitroso compounds by iron complexes. It has been observed that both N-alkyl- and N-arylhydroxylamines react with aquapentacyanoferrate-(3-) ([Fe<sup>II</sup>(CN)<sub>5</sub>·H<sub>2</sub>O]<sup>3-</sup>) with formation of the Baudisch complexes [Fe<sup>II</sup>(CN)<sub>5</sub>·RNO]<sup>3-,6</sup> Using Fe<sup>III</sup><sub>4</sub>[Fe<sup>II</sup>(CN)<sub>6</sub>]<sub>3</sub>, we could also catalyze the formation of the hetero Diels-Alder product **10** in a similar reaction as outlined in reaction 2. Similarly Fe<sup>III</sup>(TPP)(Cl) is found to dismutate *i*-PrNHOH to Fe<sup>II</sup>(TPP)(*i*-PrNO)(py) and *i*-PrNH<sub>2</sub>.<sup>8</sup> In relation to the latter observation it should be pointed out that our prior investigations showed that Fe<sup>III</sup>(TPP)(Cl) is also active as a catalyst for the allylic amination reaction.<sup>2g</sup>

We have also been examining *N*-tert-butylhydroxylamine and *N*-tert-butylhydroxylamine HCl as the nitrogen fragment donor and  $Fe^{II}Pc$  as the catalyst, but only Notes

small amounts of the amination product were observed.<sup>2g</sup> This is now readily explained by the low Diels—Alder and ene reactivity found for this type of nitroso compounds.<sup>3b</sup>

Further indications of an oxidation of aniline to nitrosobenzene come also from trapping experiments using 1,3-cyclohexadiene as the diene. It is found that the iodosylbenzene— $Fe^{II}Pc$  system can catalyze a slow oxidation of aniline to nitrosobenzene, which in the presence of 1,3-cyclohexadiene again leads to the formation of the hetero Diels—Alder product 10. The reaction of iodosylbenzene with  $Fe^{II}Pc$  leads probably to the formation of an OFe<sup>IV</sup>Pc intermediate which is responsible for the oxidation of aniline. It should be noted that the OFe<sup>IV</sup>-Pc complex, and similar types of complexes, have been postulated as intermediates in, *e.g.*, metal-catalyzed epoxidation reactions.<sup>9</sup>

These experiments show that C-nitroso compounds such as nitrosobenzene and 2-methyl-2-nitrosopropane are formed by reaction of the corresponding hydroxylamines in the presence of a catalytic amount of  $Fe^{II}Pc$ and that the high-valent  $OFe^{IV}Pc$  formed is able to oxidize N-phenylhydroxylamine and aniline to nitrosobenzene.

2. Ene Reaction of Nitroso Compounds with Alkenes. The next step in the mechanism outlined in Scheme 1 assumes that nitrosobenzene 3 reacts with the alkene 2, giving the allylic hydroxylamine 4, which then is subsequently deoxygenated to the allylic amine 1. With regard to the ene reaction of C-nitroso compounds with alkenes, it is known that 2,3-dimethylbut-2-ene (2a) reacts with nitrosobenzene to give N-phenyl-N-(1,1,2trimethylprop-2-enyl)hydroxylamine (4a) (reaction 3), which has been described as a relatively unstable compound.<sup>10a-1</sup> We have succeeded in the isolation and characterization of N-phenyl-N-(1,1,2-trimethylprop-2enyl)hydroxylamine, and its chemistry, in relation to the present investigation, will be presented in the following. It has also been observed that acylnitroso compounds react with alkenes to give relatively stable N-alkylhydroxamic acids.<sup>10k</sup> Furthermore, nitrosobenzene has recently been shown to react with 2-methyl-2-hexene at 70 °C to give the corresponding 3-(N-phenylhydroxylamino)-2-methylhex-1-ene.<sup>2i</sup>



These results thus show that an alkene can react with free nitrosobenzene to give a hydroxylamine.<sup>11</sup>

3. Deoxygenation of Hydroxylamines by Iron Complexes. The next step in the iron-catalyzed allylic amination reaction is proposed to be the deoxygenation

<sup>(5)</sup> Timberland, J. W.; Stowell, J. C. In *The Chemistry of the Hydrazo, Azo and Azoxy Groups;* Patai, S., Ed.; Wiley Interscience: London, 1975; Chapter 4.

<sup>(6)</sup> Waters, W. A. J. Chem. Soc., Perkin Trans. 2 1976, 732.

<sup>(7)</sup> Aryl- and alkylhydroxylamines have been shown to autoxidize readily even without a catalyst present. See, for example: (a) Lindeke, B.; Anderson, E.; Lundkvist, G.; Jonsson, U.; Eriksson, S. E. Acta Pharm. Suec. 1975, 12, 183. (b) Bowman, D. F.; Brokenshire, J. L.; Gillan, T.; Ingold, K. U. J. Am. Chem. Soc. 1971, 93, 6551. (c) Berti, C. Synthesis 1983, 793. (d) Sulivan, A. B. J. Org. Chem. 1966, 31, 2811. (8) (a) Mansuy, D.; Battioni, P.; Chottard, J.-C.; Lange, M. J. Am.

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<sup>(11)</sup> See especially ref 10c and references cited therein.

of the hydroxylamine to give the allylic amine. Reaction of N-phenyl-N-(1,1,2-trimethylprop-2-enyl)hydroxylamine (4a) in the presence of  $Fe^{II}Pc$  leads to the formation the 2-methyl-3-(phenylamino)propene (1a) in 27% yield (reaction 4), as opposed to the simple heating of N-phenyl-N-(1,1,2-trimethylprop-2-enyl)hydroxylamine 4a which decomposes without the formation of the allylic amine.<sup>12</sup> This shows that the catalyst in the iron-catalyzed allylic amination reaction can also be responsible for the deoxygenation of the hydroxylamine to the allylic amine.

Another piece of evidence for the involvement of a highvalent Fe<sup>n</sup>Pc (n = 3 or 4) redox catalyst in the allylic amination reaction as presented in Scheme 1 comes from the reaction outlined in reaction 5. Apart from the expected secondary amines 2-phenyl-3-(phenylamino)propene (1b) and 2-phenyl-3-[(p-methylphenyl)amino]propene (1c), the symmetric products 12 and 13 are detected by GC/MS. The formation of 1c is a further evidence for the oxidation of an aromatic amine to a species, probably a nitroso compound, which can enter the catalytic cycle.



The compounds 12 and 13 can be formed by reaction of the initially formed hydroxylamine with  $\alpha$ -methylstyrene (2b) under elimination of H<sub>2</sub>O. This fact complicates a simple interpretation of the results but does not overule the fact that the proposed mechanism is the major product path. The GC/MS analysis states that only minor amounts of the symmetrical product were formed when compared with the normal products. Moreover the amount of phenyl-3-[(p-methylphenyl)amino]propene (1c) is also minor when compared with the amount of 2-phenyl-3-(phenylamino)propene (1b), indicating a relatively slow oxidation of p-toluidine (8b) to the corresponding nitroso compound.

The deoxygenation of hydroxylamines by  $Fe^{II}Pc$  leads to an oxidation of  $Fe^{II}Pc$  yielding an intermediate, probably  $OFe^{IV}Pc$ , which can oxidize another species. The formation of an oxidized  $Fe^{II}Pc$  intermediate from *N*phenylhydroxylamine and  $Fe^{II}Pc$  is shown by reaction 6 where triphenylphosphine (14) is oxidized to triphenylphosphine oxide (15), and this reaction does not proceed without the presence of  $Fe^{II}Pc$ . It should also be noted that the reaction of iodosylbenzene with triphenylphosphine in the presence of a catalytic amount of  $Fe^{II}Pc$  leads to the formation of triphenylphosphine oxide.

$$\begin{array}{cccc} Ph-NHOH &+ & Ph_3P & & Ph_3P=O & (6) \\ \hline 7 & 14 & 15 \end{array}$$

The question is now whether the reaction occurs as an on- or off-metal reaction. We have shown that the complete reaction sequence can be carried out in three discrete steps, where the amination process (the ene reaction) can proceed without the presence of a catalyst. This we propose to be an off-metal sequence. The investigations are primarily carried out using 2,3-dimethylbut-2-ene (2a) as the alkene, and it should be mentioned that 2-methyl-3-(phenylamino)propene (1a) is obtained from N-phenylhydroxylamine and 2,3-dimethylbut-2-ene in 6% yield under simplified allylic amination conditions where the reaction is performed as a simple one-pot procedure without the essential slow addition of N-phenylhydroxylamine.<sup>13,14</sup> The reaction might therefore proceed as an off-metal reaction. However, recently Nicholas et al. have proposed the reaction to be an onmetal reaction, *i.e.*, the reaction takes place in the sphere of the catalyst.<sup>2i</sup> They did their examination with  $\alpha$ methylstyrene as the alkene and, our results with this alkene indicate that the catalyst is crucial for the catalytic cycle outlined in Scheme 1.

Unfortunately, we have never been able to isolate the hydroxylamine formed by the ene reaction of nitrosobenzene and  $\alpha$ -methylstyrene, although  $\alpha$ -methylstyrene is one of the best substrates for the amination reaction.<sup>2f,g,i</sup> This might be due to the instability of the hydroxylamine formed by the ene reaction of nitrosobenzene with 2,3dimethylbut-2-ene (**2a**),<sup>15</sup> which in the presence of Fe<sup>II</sup>-Pc is irreversible deoxygenated, or because of the higher ene reactivity of N-coordinated nitrosobenzene. To support this we examined the reaction of  $\alpha$ -methylstyrene (**2b**) and nitrosobenzene (**3**), but this time with the addition of Fe<sup>II</sup>Pc, and the deoxygenated product 2-phenyl-3-(phenylamino)propene (**1b**) was formed in 21% yield (reaction 7).



Reaction 7 clearly demonstrates the importance of the Fe<sup>II</sup>Pc and that nitrosobenzene probably is the actual aminating species.

<sup>(12)</sup> It should be mentioned that some analogous hydroxylamines have been deoxygenated by a thermal pathway. See, for example: (a) References 10c,f and references cited therein. (b) Cain, M. E.; Knight, G. T.; Lewis, P. M.; Saville, B. Rubber J. **1968**, *150*, 10.

<sup>(13)</sup> For experimental details, see ref 2g.

<sup>(14)</sup> In our original paper<sup>2g</sup> compound **1d** was presented to give the allylic amine **2d** in high yield, a product which seems to be out of line with the other experimental results. Unfoutunately, we have not been able to repeat this experiment; instead a low yield of the corrsponding exocyclic allylic amine is produced.

<sup>(15)</sup> See also: Ortiz de Montellano, P. R. In *Cytochrome P 450*; Ortiz de Montellano, P. R., Ed.; Plenum Press: New York, 1986; pp 283-284.

In summary we have shown that the mechanism for the iron-catalyzed allylic amination reaction using Nphenylhydroxylamine as the nitrogen fragment donor probably occurs as an ene reaction between nitrosobenzene and the alkene, leading to a hydroxylamine which is subsequently deoxygenated to the allylic amine. The role of the iron complex is to form nitrosobenzene from N-phenylhydroxylamine, either as a disproportionation catalyst or as an oxidation catalyst. Furthermore, the catalyst plays a crucial role in the formation of the allylic amine from the hydroxylamine formed by the reaction of nitrosobenzene with the alkene. At the present stage we are not able to fully account for the role of the iron complex in the ene reaction of nitrosobenzene and the alkene, but this reaction can proceed without the presence of a catalyst. The catalytic properties of the iron complex in these allylic amination reactions is thus probably as a disproportionation and/or redox/oxidation catalyst.

### **Experimental Section**

Apparatus. <sup>1</sup>H NMR spectra were recorded at 300 MHz and <sup>13</sup>C NMR spectra at 75 MHz using  $CDCl_3$  as the solvent and  $SiMe_4$  as internal standard. GC/MS were recorded on an OV101 column.

**Chemicals.** The solvents were purified and dried by standard methods. Compounds **2a**, **2b**, **3**, **5**, **9**, **8b**, **12a**, **13**, **14**, and **15** are commercially available and used without further purification. Compounds **1a**,  ${}^{2g}$  **1b**,  ${}^{2g}$  and *N*-phenylhydroxylamine (7)<sup>16</sup> were prepared according to the literature. PLC was performed on 1.8 mm silica gel plates. TLC was on Merck silica gel 60  $F_{254}$  plates and UV-visualized.

Reaction of N-Phenylhydroxylamine (7) with 1,3-Cyclohexadiene (9) in the Presence of Fe<sup>II</sup>Pc as the Catalyst. 7 (22 mg, 0.20 mmol) was dissolved in 1 mL of toluene. Fe<sup>II</sup>Pc (11 mg, 0.02 mmol) was added together with 30 mg of 9 (0.38 mmol), and the solution was stirred at 60 °C for 3 h. The reaction mixture (rm) was filtered through a plug of silica (1.5  $\times$  2 cm) with Et<sub>2</sub>O. After evaporation *in vacuo* the crude product was purified on PLC using 2:3 Et<sub>2</sub>O/petroleum ether as eluent. Yield: 23 mg of 10 (60%).

**3-Phenyl-2-oxa-3-azabicyclo[2.2.2]oct-5-ene (10):**<sup>17</sup> <sup>1</sup>H NMR 1.34-1.41 (m, 1H), 1.54-1.62 (m, 1H), 2.19-2.37 (m, 2H), 4.42-4.45 (m, 1H), 4.70-4.73 (m, 1H), 6.13-6.17 (m, 1H), 6.57-6.61 (m, 1H), 6.91-7.04 (m, 3H), 7.19-7.25 (m, 2H).

Reaction of Nitrosobenzene (3) with 2,3-Dimethyl-2butene (2a). 2a (2.1 g, 25 mmol) was dissolved in 50 mL of Et<sub>2</sub>O, and 0.54 g of 3 (5 mmol) was added. The rm was stirred

(16) Vogel, A. I. Textbook of Practical Organic Chemistry, 5th ed., Longmann Scientific & Technical: New York, 1989; p 955.

(17) McDonald, R. N.; Reineke, C. E. J. Org. Chem. 1967, 32, 1878.

at rt for 20 h. The rm was evaporated until absolute dryness. The crude product was dissolved in 15 mL of petroleum ether and cooled down to -78 °C. Filtration yields 440 mg of 4a (46%).

**N-Phenyl-N-(1,1,2-trimethylallyl)hydroxylamine (4a):**<sup>10a</sup> <sup>1</sup>H NMR 1.22 (s, 6H), 1.95 (s, 3H), 4.92-4.96 (br m, 2H), 7.10 (br s, 1H), 7.26 (s, 5H).

Amination of 2,3-Dimethyl-2-butene (2a) Using N-Phenylhydroxylamine (7) and Fe<sup>II</sup>Pc as the Catalyst. 2a (329 mg, 4.0 mmol) was dissolved in 3 mL of toluene. Fe<sup>II</sup>Pc (57 mg, 0.1 mmol) was added together with 109 mg of 7 (1.0 mmol), and the rm was stirred at 73 °C for 18 h. The rm was filtered through a plug of  $Al_2O_3$  (1.5 × 2 cm) with Et<sub>2</sub>O. After concentration *in vacuo* the crude product was purified on PLC using 1:9 CH<sub>2</sub>Cl<sub>2</sub>/petroleum ether as eluent. Yield: 11 mg 2b (6%).

**Phenyl(1,1,2-trimethylallyl)amine** (1a):<sup>10h</sup> <sup>1</sup>H NMR 1.43 (s, 6H), 1.79 (s, 3H), 3.68 (br s, 1H), 4.91–4.93 (m, 1H), 5.01 (s, 1H), 6.62–6.68 (m, 3H), 7.07–7.13 (m, 2H).

**Deoxygenation of N-Phenyl-N-(1,1,2-trimethylallyl)hydroxylamine (4a). 4a** (48 mg, 0.25 mmol) was dissolved in 2 mL of toluene. Fe<sup>II</sup>Pc (114 mg, 0.25 mmol) was added, and the rm was stirred at 100 °C for 21 h. The rm was filtered through a plug of silica ( $1.5 \times 2$  cm) with Et<sub>2</sub>O. After evaporation *in vacuo* the crude product was purified on PLC using 3:7 CH<sub>2</sub>Cl<sub>2</sub>/ petroleum ether as eluent. Yield: 12 mg of 1a (27%).

Reaction of Nitrosobenzene (3), p-Toluidine (8b), and a-Methylstyrene (2b) in the Presence of  $Fe^{II}Pc$  as the Catalyst. 2b (885 mg, 7.5 mmol) was dissolved in 15 mL of toluene.  $Fe^{II}Pc$  (85 mg, 0.15 mmol), and 80 mg of p-toluidine (8b) (0.75 mmol) was added. The nitrosobenzene (80 mg, 75 mmol) dissolved in 15 mL of toluene was added dropwise (1 h) to the refluxing solution. After 2 h of reflux the rm was left to cool down to rt. Then 20 mL of petroleum ether was added, and the rm was filtered through a plug of silica (1.5  $\times$  2 cm) with petroleum ether. GC/MS was run on the crude reaction product.

Oxidation of Triphenylphosphine (14) with N-Phenylhydroxylamine (7) and Fe<sup>II</sup>Pc as the Catalyst. 7 (20 mg, 0.18 mmol), 48 mg of triphenylphosphine (14) (0.18 mmol), and 11 mg of Fe<sup>II</sup>Pc (0.019 mmol) were dissolved in 2 mL of toluene. The rm was stirred at rt for 1 h. TLC (8:2 CH<sub>2</sub>Cl<sub>2</sub>/Et<sub>2</sub>O) and <sup>1</sup>H NMR of the crude product after filtration through silica and comparison with an authentic NMR sample reveals the presence of triphenylphosphine oxide.

Reaction of Nitrosobenzene (3) with  $\alpha$ -Methylstyrene (2b) and Fe<sup>II</sup>Pc as the Catalyst. 2b (295 mg, 2.5 mmol) was dissolved in 15 mL of toluene. Fe<sup>II</sup>Pc (120 mg, 0.21 mmol) was added together with 54 mg of 3 (0.5 mmol), and the rm was stirred at 110 °C for 17 h. The rm was filtered through a plug of silica (1.5  $\times$  2 cm) with Et<sub>2</sub>O. After concentration *in vacuo* the crude product was purified on PLC using 1:9 CH<sub>2</sub>Cl<sub>2</sub>/ petroleum ether as eluent. Yield: 22 mg of 1b (21%).

**Phenyl(2-phenylallyl)amine (1b):** <sup>1</sup>H NMR 3.88 (br s, 1H), 4.16 (br s, 2H), 5.34 (d, J = 1.1 Hz, 1H), 5.49 (d, J = 1.1 Hz, 1H), 6.61-6.78, 7.14-7.49 (m, 10H).

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