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The Synthesis of N-Substituted Ureas II: Nucleophilic Substitution of Ureas at the Carbonyl Group

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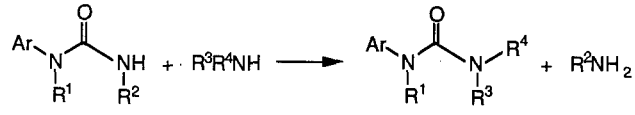
Summary. N-Arylsubstituted ureas undergo exchange of the N′-residue upon reaction with amines. Using kinetic measurements, investigation of product distribution, regioselectivity, catalysis, and substrate influences, it was shown that this reaction proceeds via a second order nucleophilic substitution at the urea carbonyl center. By means of semiempirical calculations using the MNDO method the alternative mechanism of fragmentation was investigated.

Keywords. N-substituted ureas; N-Alkylation; Arylureas; MNDO calculations; Nucleophilic substitution.

Zur Synthese N-substituierter Harnstoffe II: Nucleophile Substitution von Harnstoffen an der Carbonylgruppe

Zusammenfassung. N-Arylsubstituierte Harnstoffe erleiden bei der Reaktion mit Aminen einen Austausch des N′-Restes. Durch kinetische Messungen, Untersuchung der Produktverteilung, Regioselektivität, Katalyse und des Einflusses des Edukts konnte abgeleitet werden, daß es sich hiebei um eine nucleophile Substitution zweiter Ordnung am Carbonylzentrum des Harnstoffs handelt. Durch semiempirische Rechnungen mit Hilfe der MNDO Methode wurde der alternative Reaktionsmechanismus einer Fragmentierung untersucht.



Introduction

As discussed in the preceding paper [1], N-alkylation of aliphatic ureas provides an efficient way to synthesize N-alkylated and N,N′-dialkylated ureas avoiding the ecologically troublesome isocyanate or phosgene pathways [2]. However, the methods involving dipolar aprotic solvents and phase transfer catalysis, which were used [1], are only effective in the case of urea and N-alkylated ureas. The goal of extending this methodology to N-arylureas could be envisaged by executing a nucleophilic substitution at the urea carbonyl group according to the formula scheme (R^1, R^2, R^3, R^4 ... H, alkyl; *Ar* ... aryl).

There are several reports in literature in which a formal substitution at the urea carbon takes place with amines [2]. These reactions are thought to occur via a

thermal fragmentation of the substituted urea into an isocyanate which then reacts with the amine. Drastic reaction conditions and lack of regioselectivity in the case of urea and alkylurea transformations are the main evidences of these mechanistic details.

However, besides the reactive behavior of urea and alkylureas, this reaction seems to be regioselective in the case of arylureas [2]. Thus, this latter evidence and the observation that N-phenylurea and N,N-diphenylurea is attacked at the carbonyl carbon atom by the nucleophilic hydroxide ion [1] triggered our investigation of the nucleophilic substitution of N-arylureas by alkylamines to obtain N-aryl-N′-alkylureas.

Results and Discussion

As shown in Table 1 N-phenylurea (**1**) reacts regioselectively with several primary and secondary amines in refluxing xylene to yield N-phenyl-N′-substituted ureas. Two remarkable points may be mentioned: **1** and amine are used in equimolar concentrations, and no side reactions are observed within the reaction times used. Therefore the time-dependent turnover is given in Table 1 instead of yields. However, only amines with a basicity (and nucleophilicity) which is sufficiently high will react: diphenylamine did not react with **1**. The turnover is also strongly influ-

Table 1. Nucleophilic substitution of N-phenylurea (**1**) with primary and secondary amines

Amine	Product	Time (h)	Turnover (%)
Aniline	N,N′-Diphenylurea	1.0	>90
Aniline	N,N′-Diphenylurea	0.5	70
Dioctylamine	N-Phenyl-N′,N′-dioctyl-urea	1.0	83
Dioctylamine	N-Phenyl-N′,N′-dioctyl-urea	0.5	70
tert-Butylamine	N-Phenyl-N′-*tert*-butyl-urea	0.5	50
2,6-Diisopropylaniline	N-Phenyl-N′-diisopropylphenylurea	0.5	13
Morpholine	N′-Phenyl-morpholine-N-Carboxamide	0.5	85
Pyrrolidine	N′-Phenyl-pyrrolidine-N-Carboxamide	0.5	60

Table 2. Reactions of N-substituted ureas with N,N-dioctylamine

Urea	Product	Time (h)	Turnover (%)
N,N-Diphenylurea	none	1.0	0
N-*tert*-Butyl-N′-butylurea	none	0.5	0
N-4-Methoxyphenylurea	N-4-Methoxyphenyl-N′,N′-dioctyl-Urea	0.5	62
N-4-Dimethylamino-Phenylurea	N-4-Dimethylaminophenyl-N′,N′-Dioctylurea	0.5	44
N-4-Chlorophenylurea	N-4-Dichlorophenyl-N′,N′-dioctylurea	0.5	20
N-4-Nitrophenylurea	N-4-Nitrophenyl-N′,N′-dioctylurea	0.5	[a]
N-Phenyl-N′-propylurea	N-Phenyl-N′,N′-dioctylurea	0.5	35

[a] Due to the insolubility of 4-nitrophenylurea in boiling xylene quantitative turnover could not be measured. However, this urea obviously reacts faster than **1**

enced by the steric requirements of substituents as observed, for example, comparing the turnovers of aniline and 2,6-diisopropylaniline.

This kind of reaction is not limited to **1** as the substrate. Table 2 contains arylureas substituted at the aromatic ring or alkylated at the second urea nitrogen atom. For convenience, N,N-dioctylamine was chosen as the reagent in these examples.

According to the examples of Table 2 N,N-diaryl disubstituted and N,N′-dialkyl disubstituted ureas will not react with primary and secondary amines. In these cases the educts were recovered quantitatively. N,N-diphenylurea does not react with amines, but it is only attacked by the hydroxyl ion to yield carbamic acid and ammonia, and eventually diphenylamine. However, N,N-diphenylurea is not cleaved by thermal stress as exerted by refluxing xylene in the absence of a suited nucleophile. As evidenced by the example of Table 2 an N′-alkyl-substituent also strongly disfavors the reaction of N-phenylureas. This accounts nicely for the "clean" regioselective reaction without any side reactions, because obviously a once alkyl substituted product is protected against further attack. However, it has to be realized that prolonged reaction times or an increase in the reaction temperature may lead to a loss of regioselectivity due to thermal decomposition pathways. The example of N-*tert*-butyl-N′-butylurea also points strongly against a sterically favored decomposition mechanism [3] under the experimental conditions used.

Mechanistic Aspects

With respect to mechanistic details, the evidences presented above, including an absence of any byproducts and the regioselectivity of the reaction for the reaction conditions used, clearly point to a nuclephilic substitution reaction at the urea carbonyl carbon atom. However, these results are not in agreement with a mechanism involving decomposition of the urea into amine and isocyanate which eventually reacts with the reagent amine as inferred earlier [4]. Accordingly, in the case of **1** such a fragmentation-addition mechanism would lead to the formation of aniline, isocyanic acid, phenylisocyanate, and ammonia, which is observed only under more drastic conditions [5]. These should yield a mixture of several products upon reaction with the reagent amine, which is not the case. The absence of these degradation products of **1** under the reaction conditions used could also be corroborated by an NMR experiment. A solution of **1** in bromobenzene-d_5 kept at 130°C showed no evidence of the formation of any isocyanate or aniline within half an hour in its ^{1}H- and ^{13}C-NMR-spectra.

The regioselectivity of such a nucleophilic substitution at the urea carbonyl atom may be advanced by comparing the basicities of the respective leaving particles. Thus the most basic one (ammonia or alkyl amines) will be expected to leave, the weaker one (aniline) should remain in place.

As shown by the data of Table 2 the influence of the electronic effects of substituents in position 4 of the phenyl ring of N-arylureas on their reactivity with respect to substitution by amines seems to be moderate. This behavior may be due to the torsional deformation of the aryl−nitrogen bond derived from the steric requirements of aryl protons and the carbonyl group. This kind of deformation is nicely evident from an X-ray structural analysis of **1** [6, 7].

Previous kinetic investigations claimed the reaction to be of first order with

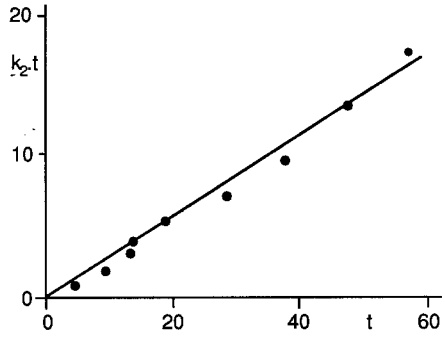


Fig. 1. Second order kinetics of the reaction of **1** with N,N-dioctylamine in refluxing xylene, concentrations 0.1 mol l^{-1}

respect to the concentration of the substrate urea, and being catalyzed by the reagent amine in the fragmentation step [4]. These kinetic data may also be interpreted in principle as a pseudo first order reaction under the reaction conditions used. Moreover, it was observed that addition of one mole of a non nucleophilic base (N-ethyl-N,N-diisopropylamine) to N-4-methoxyphenylurea in refluxing xylene did not lead to decomposition as could be expected of a base catalyzed reaction.

Kinetic measurements on the system **1**/N,N-dioctylamine in refluxing xylene (140°C) revealed a behavior which is characteristic of second order reactions: as shown in Fig. 1 plotting the product of the velocity constant and reaction time, k_2t, versus the reaction time yields a straight line. From these data a second order velocity constant $k_2 = 0.29\,l\,mol^{-1}\,min^{-1}$ was derived. It should be mentioned that with rising substrate and reagent concentrations the velocity constant is reduced. This can be attributed to a change in polarity of the apolar reaction medium.

Direct ^{1}H-NMR observation of the reaction velocities of **1** and N,N-dioctylamine in 1,2-dichlorobenzene at 120 and 130°C provided an estimation of approximately 100 kJ mol^{-1} for the Arrhenius activation energy.

On treatment of **1** with 1-pentanol in xylene at 130°C the corresponding N-phenyl-O-pentylurethane [8] is formed as evidenced from ^{1}H-NMR spectra. The second order reaction velocity k_2 of this reaction is in the order of 0.1 l mol^{-1} min^{-1}. This value is significantly reduced compared to that of the amine, and points to the smaller nucleophilicity of an alcohol compared to an amine.

Semiempirical Calculations

With respect to the mechanistic details described above, it seemed to be of interest to have a closer look into the energetic and structural details of the question of decomposition versus nucleophilic displacement. Geometric parameters of **1** and its respective ionic fragmentation products aniline plus isocyanic acid and phenylisocyanic acid plus ammonia were optimized by means of the MNDO scheme [9]. For these structures formation enthalpies were calculated using population analysis. The results (**1** $\Delta H_f = -1\,917$ kJ mol^{-1}, aniline + isocyanic acid $\Delta H_f = 51$ kJ mol^{-1}: $\Delta H_r = 1\,968$ kJ mol^{-1}; phenylisocyanate + ammonia $\Delta H_f = 33$ kJ mol^{-1}; $\Delta H_r = 1\,950$ kJ mol^{-1}) immediately revealed that there is a

rather high reaction enthalpy necessary to break the bonds, and that the enthalpy difference between the two reaction paths is rather small. Therefore, in the light of the activation energy of about 100 kJ mol^{-1} as derived above, we have to expect at the moderate temperatures used in our experiments a predominant reaction not by fragmentation, but by other available routes, and a weak regioselectivity of fragmentation reactions at elevated temperatures. This result from semiempirical calculations is in agreement with the experimental data given above. It may be interesting to mention that the geometry of **1** as derived from the MNDO optimization compares favorably with the data obtained by X-ray crystallography [6]. For example, the dihedral angle between the phenyl ring and the plane containing the HN − C = O group is calculated to be 38° − the experimental value was measured to be 46.4° [6].

Conclusions

All evidences obtained from kinetic measurements, investigations of substrate influence, catalysis, regioselectivity, product distribution, and semiempirical calculations as presented above favour a second order nucleophilic substitution of N-arylureas with an amine at the N-arylurea carbonyl center. Thereby a mechanism involving decomposition into isocyanate and amine as the first and rate determining step as postulated in literature [4] can be ruled out for moderate reaction temperatures. This kind of synthesis limited to arylureas nicely complements the alkylation procedure described recently which is limited to alkylureas.

Experimental Part

Melting points were taken by means of differential scanning calorimetry using a Perkin Elmer DSC 2 apparatus. The scanning rate was 20°C/min and the peak onset was recorded as the melting point. ^{1}H-, ^{13}C-, IR-, and M-spectra were recorded using the Bruker AC-200-, Biorad FTS-45-, and Digilab FTS-20E-instruments and Varian 331-A-instruments.

Reactions

1 mmol of **1** or a substituted arylurea and 1 mmol of amine were suspended or dissolved in 5 ml xylene, well stirred, and kept under reflux for a reaction time of 20 to 180 minutes. The apparatus is an open system, and released ammonia is adsorbed. The reaction mixture obtained in this way was worked up according to procedures (A) or (B) as indicated.

Workup Procedure (A)

Since most monosubstituted arylureas are insoluble in cold aromatic hydrocarbons whereas most N-aryl-N′-alkylureas are soluble (valid for all mentioned examples), the reaction mixture was cooled to 20°C, filtered from any remaining educt which is suitable for further use as educt and the solvent (and any remaining amine) is removed under reduced pressure. If the product is a solid it may be purified by crystallization.

Workup Procedure (B)

The warm (50 − 80°C) reaction mixture is attached to vacuum in order to remove xylene and unreacted amine and the residue is extracted with 1 ml chloroform at 20°C. The solvent is removed under

reduced pressure, in the case of high boiling amines column chromatography is the method of choice. If the product is a solid it can be purified by crystallization.

Kinetic Measurements

1 and dioctylamine were reacted according to the procedure given above (concentrations and reaction times according to Fig. 1) and worked up using method (**B**) without removing dioctylamine, but taking $CDCl_3$ instead of $CHCl_3$ as the extraction solvent. The turnover was determined by means of ^{1}H-NMR spectra of the extracts: the ratio of the amine $N-CH_2$ signal at 2.57 ppm and the product urea $N-CH_2$ signal at 3.28 ppm were evaluated. Arrhenius activation energy was estimated from the direct measurement of ^{1}H-NMR-signals of samples dissolved in 1,2-dichlorobenzene at 120 and 130°C.

1 and the amines mentioned in Tables 1 and 2 were of commercial origin (Fluka). N-*tert*-butyl-N′-butylurea, N-4-chlorophenylurea, N-4-methoxyphenylurea (in analogy to N-4-ethoxyphenylurea [10]), N,N′-diphenylurea, N,N-diphenylurea, N-4-dimethylaminophenylurea, N-phenyl-N′-propylurea, and N-4-nitrophenylurea were prepared according to [1, 10–16].

N-Phenyl-N′,N′-dioctylurea [$C_{23}H_{40}N_2O$]

Prepared according to the procedure described above from 2.41 g (10 mmol) dioctylamine and 1.36 g (10 mmol) **1** and worked up according to (**B**). Turnover after 60 minutes: 83%; liquid. ^{1}H-NMR (200 MHz, δ, $CDCl_3$): 7.38 (m, 2 H, phenyl-2 and 6, J_{ortho} 23 = 8.4 Hz, J_{meta} = 1.3 Hz), 7.26 (m, 2 H, phenyl-3 and 5, $J_{ortho\,23}$ = 8.4 Hz, $J_{ortho\,34}$ = 7.2 Hz), 7.00 (m, 1 H, phenyl-4, J_{meta} = 1.3 Hz, $J_{ortho\,34}$ = 7.2 Hz), 6.29 (s, 1 H, NH), 3.27 (t, 4 H, octyl-1, $J_{CH_2CH_2}$ = 7.4 Hz), 1.61 (tt, 4 H, octyl-2, $J_{CH_2CH_2}$ = 7.4 Hz), 1.29 (m, 20 H, octyl-3–7, $J_{CH_2CH_3}$ = 6.3 Hz), 0.88 (t, 6 H, octyl-8, $J_{CH_2CH_3}$ = 6.3 Hz) ppm. ^{13}C-NMR (50 MHz, δ, $CDCl_3$): 154.9 (C=O), 139.4 (CH, phenyl-1), 128.8 (CH, phenyl-3 and 5), 122.7 (CH, phenyl-4), 119.7 (CH, phenyl-2 and 6), 47.8 (CH_2, octyl-1), 31.8, 29.4, 29.3, 28.7, 27.1 and 22.7 (CH_2, octyl-2–7), 14.1 (CH_3, octyl-8) ppm. IR ($CHCl_3$): 2 928, 1 654, 1 524, 1 439, 1 308 cm^{-1}. MS (70 eV, 40°C): *m*/e (%) = 268 (4, *M*-92), 143 (100), 85 (12), 83 (19), 71 (14), 70 (6), 69 (6), 57 (23), 56 (7), 55 (11), 46 (5), 44 (86), 43 (29), 42 (6), 41 (22), 32 (9). R_f (SiO_2; $CHCl_3/CH_3OH$ = 20/1): 0.8.

N-4-Methoxyphenyl-N′,N′-dioctylurea [$C_{24}H_{42}N_2O_2$]

Prepared using the procedure described above from 2.41 g (10 mmol) dioctylamine and 1.66 g (10 mmol) N-4-methoxyphenylurea and worked up according to (**B**) and crystallization from $CHCl_3$. Turnover after 30 minutes: 62%. M.p. 47.9°C; ^{1}H-NMR (200 MHz, δ, *DMSO-d*$_6$): 7.94 (s, 1 H, NH), 7.31 and 6.78 (m, 2 × 2 H; methoxyphenyl-2,3,5 and 6, J_{ortho} = 9.0 Hz), 3.68 (s, 3 H, OCH_3), 3.22 (t, 4 H, octyl-1, $J_{CH_2CH_2}$ = 7.2 Hz), 1.46 (m, 4 H, octyl-2, $J_{CH_2CH_2}$ = 7.2 Hz), 1.24 (m, 20 H, octyl-3–7, $J_{CH_2CH_3}$ = 6.4 Hz), 0.84 (t, 6 H, octyl-8, $J_{CH_2CH_3}$ = 6.4 Hz) ppm. ^{13}C-NMR (50 MHz, δ, *DMSO-d*$_6$): 155.1 (C=O), 154.4 (C, methoxyphenyl-4), 133.7 (C, methoxyphenyl-1), 121.9 and 113.28 (CH, methoxyphenyl-2,3,5 and 6), 55.1 (OCH_3), 46.2 (CH_2, octyl-1), 31.3, 28.9, 28.7, 28.2, 26.3, and 22.1 (CH_2, octyl-2–7), 13.9 (CH_3, octyl-8) ppm. IR (KBr): 3 311, 1 634, 1 601, 1 512, 1 228, 825 cm^{-1}. MS (70 eV, 145°C): *m*/e (%) = 291 (2, *M*-99), 268 (12), 149 (37), 143 (15), 142 (100), 134 (20), 123 (9), 106 (9), 71 (53), 69 (8), 57 (57), 55 (11), 44 (54), 43 (31), 40 (16). R_f (SiO_2; $CHCl_3/CH_3OH$ = 20/1): 0.9

N-4-Chlorophenyl-N′,N-dioctylurea [$C_{23}H_{39}N_2OCl$]

Prepared using the procedure described above from 2.41 g (10 mmol) dioctylamine and 1.71 g (10 mmol) N-4-chlorophenylurea and worked up according to (**B**). Turnover after 30 minutes: 20%; liquid. ^{1}H-NMR (200 MHz, δ, *DMSO-d*$_6$): 8.23 (s, 1 H, NH), 7.48 and 7.24 (m, 2 H each, chlorophenyl-

2,3,5 and 6, J_{ortho} = 8.9 Hz), 3.24 (t, 4H, octyl-1, $J_{CH_2CH_2}$ = 7.2 Hz), 1.46 (m, 4H, octyl-2, $J_{CH_2CH_2}$ = 7.2 Hz), 1.23 (m, 20H, octyl-3 – 7, $J_{CH_2CH_3}$ = 6.4 Hz), 0.83 (t, 6H, octyl-8, $J_{CH_2CH_3}$ = 6.4 Hz) ppm. ^{13}C-NMR (50 MHz, δ, *DMSO-d*$_6$): 154.6 (C=O), 139.7 (C, chlorophenyl-4), 127.9 and 121.1 (CH, chlorophenyl-2,3,5 und 6), 125.0 (C, chlorophenyl-1), 46.1 (CH_2, octyl-1), 31.2, 28.8, 28.6, 28.0, 26.2 and 22.0 (CH_2, octyl-2 – 7), 13.8 (CH_3, octyl-8) ppm. IR ($CHCl_3$): 2931, 1662, 1519, 1493, 1416 cm^{-1}. MS (70 eV, 70°C): *m*/e (%) = 202 (2, *M*-193), 201 (20), 200 (6), 199 (62), 171 (8), 154 (7), 153 (12), 142 (20), 140 (61), 129 (33), 128 (15), 127 (100), 126 (26), 125 (8), 111 (6), 101 (8), 100 (9), 99 (25), 92 (10), 91 (9), 90 (12), 83 (8), 75 (10), 73 (9), 65 (11), 64 (9), 63 (17), 45 (8), 39 (11), 38 (7), 32 (16). R_f (SiO_2; $CHCl_3/CH_3OH$ = 20/1): 0.8

N-Phenyl-N'-2, 6-diisopropylphenylurea [$C_{19}H_{24}N_2O$]

Prepared using the procedure described above from 1.36 g (10 mmol) **1** and 1.77 g (10 mmol) 2,6-diisopropylaniline and worked up according to (B) and crystallization from $CHCl_3$. Turnover after 30 minutes: 13%. M.p. 233.5°C. ^{1}H-NMR (200 MHz, δ, *DMSO-d*$_6$): 8.76 (s, 1H, phenyl-NH), 8.31 (s, 1H, DIPP-NH), 7.47 (m, 2H, phenyl-2 and 6 $J_{\text{phenyl-}ortho\,23}$ = 7.6 Hz, $J_{\text{phenyl-}meta}$ = 1.0), 7.24 (m, 2H, phenyl-3 and 5, $J_{\text{phenyl-}ortho\,34}$ = 7.3, $J_{\text{phenyl-}ortho\,23}$ = 7.6) Hz, 6.91 (m, 1H, phenyl-4, $J_{\text{phenyl-}ortho\,34}$ = 7.3 Hz, $J_{\text{phenyl-}meta}$ = 1.0), 7.28 (m, 1H, DIPP-4, $J_{\text{DIPP-}ortho\,34}$ = 6.8 Hz), 7.16 (m, 2H, DIPP-3 and 5, $J_{\text{DIPP-}ortho\,34}$ = 6.8 Hz), 3.21 (se, 2H, isopropyl-CH, J_{CHCH_3} = 6.9 Hz), 1.16 (d, 12H, isopropyl-CH_3, J_{CHCH_3} = 6.9 Hz) ppm. ^{13}C-NMR (50 MHz, δ, *DMSO-d*$_6$): 154.3 (C=O), 146.6 (C, DIPP-2 and 6), 140.3 (C, phenyl-1), 132.3 (C, DIPP-1), 128.6 (CH, phenyl-3 and 5), 127.2 (CH, DIPP-4), 122.8 (CH, DIPP-3 and 5), 121.2 (CH, phenyl-4), 117.7 (CH, phenyl-2 and 6), 28.0 (CH, isopropyl-CH), 23.5 (CH_3, isopropyl-CH_3) ppm. IR (KBr): 3320, 1645, 1597, 1560, 1499, 750 cm^{-1}. MS (70 eV, 140°C): *m*/e (%) = 296 (8, M^+), 205 (6), 204 (42), 203 (22), 188 (11), 162 (19), 120 (5), 94 (10), 93 (100), 77 (8), 43 (7), 41 (7). R_f (SiO_2; $CHCl_3/CH_3OH$ = 20/1): 0.7.

N'-Phenyl-pyrrolidine-N-carboxamide [$C_{11}H_{14}N_2O$; cf. Ref. 17]

Prepared according to the procedure described above from 1.36 g (10 mmol) **1** and 0.71 g (10 mmol) pyrrolidine and worked up according to procedure (B) and crystallization from ethanol. Turnover after 30 minutes: 60%. M.p. 135.2°C; m.p. [17] 134.5 – 135.5°C. ^{1}H-NMR (200 MHz, δ, $CDCl_3$): 7.41 (m, 2H, phenyl-2 and 6, $J_{ortho\,23}$ = 8.1 Hz, J_{meta} = 1.2 Hz), 7.22 (m, 2H, phenyl-3 and 5, $J_{ortho\,23}$ = 8.1 Hz, $J_{ortho\,34}$ = 75 Hz), 6.97 (m, 1H, phenyl-4, J_{meta} = 1.2 Hz, $J_{ortho\,34}$ = 7.5 Hz), 6.54 (s, 1H, NH), 3.38 (t, 4H, pyrrolidine-2 and 5, $J_{Pyr\,23}$ = 6.7 Hz), 1.86 (tt, 4H, pyrrolidine-3 and 4, $J_{Pyr\,23}$ = 6.7 Hz) ppm. ^{13}C-NMR (50 MHz, δ, $CDCl_3$): 154.2 (C, carbonyl), 139.5 (C, phenyl-1), 128.7 (CH, phenyl-3 and 5), 122.6 (CH, phenyl-4), 119.8 (CH, phenyl-2 and 6), 45.8 (CH_2, pyrrolidine-2 and 5), 25.5 (CH_2, pyrrolidine-3 and 4) ppm. IR (KBr): 3296, 1641, 1593, 1537, 1443, 1375, 1240 cm^{-1}.

N'-Phenyl-morpholine-N-carboxamide [$C_{11}H_{14}N_2O_2$; cf. Ref. 18]

Prepared according to the procedure described above from 1.36 g (10 mmol) **1** and 0.87 g (10 mmol) morpholine and worked up according to (B). Turnover after 30 minutes: 85%. M.p. 160.4°C; m.p.[18] 162°C. ^{1}H-NMR (200 MHz, δ, $CDCl_3$): 7.34 – 7.19 (m, 4H, phenyl-2,3,5 and 6, $J_{ortho\,23}$ = 7 3 Hz, $J_{ortho\,34}$ = 8.2 Hz), 7.07 (s, 1H, NH), 7.06 – 6.98 (m, 1H, phenyl-4, $J_{ortho\,34}$ = 8.2 Hz), 3.59 (t, 4H, morpholine-CH_2 – O, $J_{CH_2CH_2}$ = 4.7 Hz), 3.37 (t, 4H, morpholine-CH_2 – N, $J_{CH_2CH_2}$ = 4.7 Hz) ppm. ^{13}C-NMR (50 MHz, δ, $CDCl_3$): 155.6 (C=O), 139.0 (C, phenyl-1), 128.8 (CH, phenyl-3 and 5), 123.4 (CH, phenyl-4), 120.7 (CH, phenyl-2 and 6), 66.5 (CH_2, morpholine-CH_2 – O), 44.2 (CH_2, morpholine-CH_2 – N) ppm. IR (KBr): 3271, 1650, 1535, 1500, 1456 cm^{-1}.

N-4-Dimethylaminophenyl-N',N'-dioctylurea [$C_{25}H_{45}N_3O$]

Prepared according to the procedure described above from 2.41 g (10 mmol) dioctylamine and 1.79 g (10 mmol) N-4-dimethylaminophenylurea and worked up according to procedure (B). Turnover after

30 minutes: 44%; liquid. ^{1}H-NMR (200 MHz, δ, $CDCl_3$): 7.31 and 6.67 (2 m, 2 H each, phenyl-H, J_{ortho} = 9.0 Hz), 6.34 (s, 1 H, NH), 3.25 (t, 4 H, octyl-1, $J_{CH_2CH_2}$ = 7.6 Hz), 2.86 (s, 6 H, N−CH_3), 1.55 (m, 4 H, octyl-2), 1.28 (m, 20 H, octyl-3−7), 0.87 (t, 6 H, octyl-8, $J_{CH_2CH_3}$ = 6.5 Hz) ppm. ^{13}C-NMR (50 MHz, δ, $CDCl_3$): 155.6 (C=O), 147.3 (C, phenyl-1), 129.7 (C, phenyl-4), 122.3 (CH, phenyl-2 and 6), 113.5 (CH, phenyl-3 and 5), 47.6 (CH_2, octyl-1), 41.2 (CH_3, N−CH_3), 31.8, 29.4, 29.3, 28.7, 27.0 and 22.6 (CH_2, octyl-2−7), 14.0 (CH_3, octyl-8) ppm. IR ($CHCl_3$): 2938, 1650, 1525, 1502, 1312, 1253, 911 cm^{-1}. MS (70 eV, 150°C): *m*/e (%) = 241 (3), 211 (1), 162 (38), 161 (22), 142 (100), 133 (2), 113 (5), 69 (2), 57 (6), 44 (60); no molecular ion at 404 observed. R_f (SiO_2; $CHCl_3/CH_3OH$ = 20/1): 0.7.

N-4-Nitrophenyl-N',N'-dioctylurea [$C_{23}H_{39}N_3O_3$]

Prepared according to the procedure described above from 2.41 g (10 mmol) dioctylamine and 1.81 g (10 mmol) N-4-nitrophenylurea and worked up according to procedure (B). Turnover after 30 minutes: app. 5% due to insolubility of educt in refluxing xylene, liquid. ^{1}H-NMR (200 MHz, δ, $CDCl_3$): 8.16 and 7.56 (2 m, 2 H each, phenyl-H, J_{ortho} = 9.1 Hz), 6.76 (s, 1 H, NH), 3.32 (t, 4 H, octyl-1, $J_{CH_2CH_2}$ = 7.6 Hz), 1.59 (m, 4 H, octyl-2), 1.28 (m, 20 H, octyl-3−7), 0.89 (t, 6 H, octyl-8, $J_{CH_2CH_3}$ = 6.4 Hz) ppm. ^{13}C-NMR (50 MHz, δ, $CDCl_3$): 153.8 (C=O), 145.7 and 142.3 (C, phenyl-1 and 4), 125.1 and 118.3 (CH, phenyl-2,3,5 and 6), 47.6 (CH_2, octyl-1), 31.8, 29.6, 29.2, 28.7, 27.0 and 22.6 (CH_2, octyl-2−7), 14.0 (CH_3, octyl-8) ppm. IR ($CHCl_3$): 2930, 1673, 1601, 1538, 1501, 1332, 1330, 1173, 1113 cm^{-1}. MS (70 eV, 130°C): *m*/e (%) = 218 (3), 210 (100), 182 (3), 165 (8), 151 (62), 138 (49), 108 (25), 92 (22), 65 (23), 50 (8); no molecular ion at 406 observed. R_f (SiO_2; $CHCl_3/CH_3OH$ = 20/1): 0.9.

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