Practical Synthesis of Urea Derivatives from Primary Amines, Carbon Monoxide, Sulfur, and Oxygen under Mild Conditions

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Abstract: A new and facile synthetic method for urea derivatives was developed under mild conditions, and contrasts with conventional preparation methods that need highly toxic reagents (phosgene) or severe reaction conditions. In our reaction system, *N*,*N*-dimethylformamide or dimethyl sulfoxide as solvent strongly accelerated the carbonylation of primary amines with sulfur under carbon monoxide (1 atm) at 20 °C to give the corresponding thiocarbamate salts. These salts were readily oxidized by molecular oxygen under similarly mild conditions to afford urea derivatives in good to excellent yields. This urea synthesis could also be applied to a new synthesis of aromatic ureas by use of 1,8-diazabicyclo[5.4.0]undec-7-ene in *N*,*N*-dimethylformamide.

Key words: amines, amides, sulfur, carbonylations, oxidations

Urea derivatives **1** (Schemes 1 and 2) are important materials as fertilizers, agricultural chemicals, medicines, and polar solvents. Therefore, a variety of synthetic methods for **1** have been developed, based on the carbonylation of amines **2**. For example, a general synthetic method for the preparation of urea derivatives **1** includes the carbonylation of amines **2** with toxic phosgene as the carbonyl source.[1–3] Because of the toxicity of phosgene, the much safer diphosgene,[4] triphosgene,[5] and 1,1′-carbonyldiimidazole[6,7] have also been used in its place. Urea has also been recognized as a carbonyl source for the synthesis of **1**,[8,9] but then the synthesis of urea derivatives **1** from amines **2** and urea needs to be carried out at high temperatures. Carbonates have been similarly effective for the preparation of urea derivatives **1** from amines **2**.[10,11] The industrial method for the production of urea consists of the reaction of ammonia with carbon dioxide under severe reaction conditions.[12] *N*,*N*′-Dicyclohexylcarbodiimide,[13] 1,8-diazabicyclo[5.4.0]undec-7-ene,[14] and transition-metal catalysts[15,16] have also been used for the synthesis of urea derivatives **1** from carbon dioxide. Urea derivatives **1** have also been prepared from the reactions of amines **2** with carbonyl sulfide.[17]

Carbon monoxide has been a useful raw material for the preparation of ureas **1** from amines **2**. Various urea derivatives **1** have been prepared from amines **2** and carbon monoxide in the presence of transition-metal catalysts.[18–20] In 1961, the Monsanto group introduced sulfur-assisted carbonylation of primary amines **2** by carbon monoxide to give urea derivatives **1**.[21–23] However, this reaction requires high temperatures and pressurized carbon monoxide. Also, in 1971, Sonoda et al. found that selenium exhibits excellent catalytic activity toward the carbonylation of amines by carbon monoxide.[24,25] The selenium-catalyzed carbonylation of amines **2** and oxidation of ammonium salts of selenocarbamates are performed under mild conditions (1 atm, r.t.) to give urea derivatives **1** in good yields. However, the toxicity of selenium compounds has considerably limited the use of this preparative method for large-scale production of ureas **1**.

In 1993, we published a preliminary report on the carbonylation of amines **2** in tetrahydrofuran by carbon monoxide and sulfur, followed by oxidation using molecular oxygen to provide urea derivatives **1** in good yields and under mild conditions (1 atm, 20 °C).[26] However, this carbonylation was sluggish and long reaction times were necessary. Also, the method was difficult to apply to the synthesis of aromatic urea derivatives. Very recently, we reported the solvent-assisted thiocarboxylation of amines **2** by carbon monoxide and sulfur, to afford *S*-alkyl thiocarbamates in good yields.[27] In this reaction system, the thiocarboxylation of amines **2** by carbon monoxide and sulfur under mild conditions (1 atm, 20 °C) was considerably assisted by the use of dimethyl sulfoxide or *N*,*N*-dimethylformamide as solvent.

Therefore, our objective has been to develop a straightforward synthetic method for urea derivatives **1**, including aromatic urea derivatives, by the carbonylation of amines **2** by carbon monoxide and sulfur, followed by oxidation with molecular oxygen, under mild conditions (1 atm, 20 °C) in *N*,*N*-dimethylformamide or dimethyl sulfoxide. We here report the full results of the synthesis of urea derivatives **1** from amines **2**, carbon monoxide, sulfur, and oxygen by use of solvent-accelerated carbonylation under mild conditions (1 atm, 20 °C).

Our investigation into employing *N*,*N*-dimethylformamide as a solvent led to the successful synthesis of urea derivative **1a** by the carbonylation of cyclohexylamine (**2a**) with carbon monoxide and sulfur, followed by oxidation of the intermediate salt **3a** by molecular oxygen (Scheme 1). Cyclohexylamine (**2a**) readily reacted with carbon monoxide (1 atm) and sulfur (1.0 equiv) at 20 °C for four hours in *N*,*N*-dimethylformamide as solvent. The reaction mixture changed from a reddish-black solution to a pale-green emulsion, and the resulting thiocarbamate salt **3a** in *N*,*N*-dimethylformamide solution was oxidized

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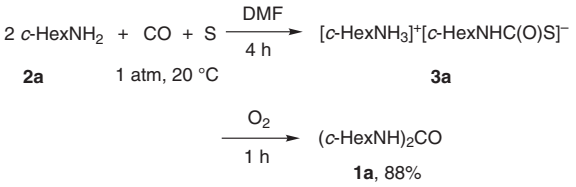
by molecular oxygen under ambient pressure at 20 °C for one hour. Finally, *N*,*N*′-dicyclohexylurea (**1a**) was obtained as a pure white solid in 88% yield based on sulfur (Scheme 1; Table 1, entry 1).



Scheme 1 Synthesis of *N*,*N*′-dicyclohexylurea

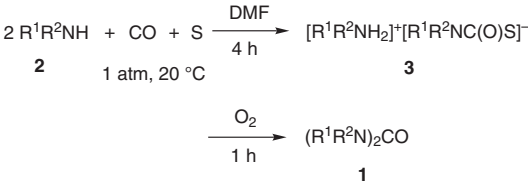
To examine the influence of solvent and reaction time on this method for the preparation of *N*,*N*′-dicyclohexylurea (**1a**), several control reactions were performed (Table 1). When dimethyl sulfoxide was employed as the solvent, a similar solvent effect was found after five hours of reaction to give urea **1a** in good yields (82%) (Table 1, entry 4). Shorter reaction times for carbonylation lowered the yields of *N*,*N*′-dicyclohexylurea (**1a**) in both *N*,*N*-dimethylformamide and dimethyl sulfoxide (Table 1, entries 2 and 5). Even when *N*,*N*′-dicyclohexylurea (**1a**) was synthesized on a tenfold scale, it was obtained in considerably good yield after a longer reaction time (27 h) (Table 1, entry 3). In contrast, the yield of urea **1a** was lower after four hours of reaction in tetrahydrofuran (Table 1, entry 6). A longer reaction time (Table 1, entry 7) gave urea **1a** in a yield similar to that obtained in *N*,*N*-dimethylformamide (Table 1, entry 1). Therefore, we believe that the solvent is a predominant factor in this urea-derivative synthesis by the carbonylation of amines **2** with carbon monoxide and sulfur followed by oxidation in molecular oxygen.

Table 1 Influence of Solvent and Reaction Time on the Synthesis of *N*,*N*′-Dicyclohexylurea

Entry	Solvent	Reaction time (h)		Isolated Yield (%)[a]
		Carbonylation	Oxidation	
1	DMF	4	1	88
2	DMF	1	0.5	49
3	DMF	24	3	79[b]
4	DMSO	4	1	82
5	DMSO	1	0.5	49
6	THF	4	1	8
7	THF	20	4	89[c]

[a] Reagents and conditions: cyclohexylamine (2.86 mL, 25 mmol), sulfur (321 mg, 10 mmol), solvent (20 mL), CO (1 atm), O_2 (1 atm), 20 °C.
[b] Cyclohexylamine (28.6 mL, 250 mmol), sulfur (3.21 g, 100 mmol), DMF (100 mL), CO (1 atm), O_2 (1 atm), 20 °C.
[c] Ref.[26]

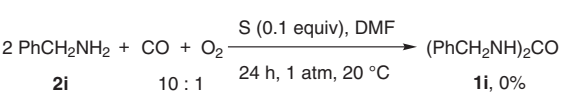
To demonstrate the efficiency and scope of this method, the preparation of a variety of urea derivatives **1a–o** from the corresponding amines **2a–o** was investigated at 1 atm, 20 °C, and for five hours in *N*,*N*-dimethylformamide (Scheme 2, Table 2).



Scheme 2 Synthesis of *N*,*N*′-dialkylureas from the corresponding amines and carbon monoxide in *N*,*N*-dimethylformamide

Primary amines **2a–c** and **2e–i** were suitable for this urea-derivative synthesis, providing *N*,*N*′-dialkylureas **1a–c** and **1e–i** in good to excellent yields under mild conditions (1 atm, 20 °C) (Table 2, entries 1–3, 5–9). *N*,*N*′-Di-*tert*-butylurea (**1d**) was obtained in moderate yield (59%) despite the bulkiness of the *tert*-butyl group (Table 2, entry 4). Also, *N*,*N*′-diphenylureas **1j–l** were successfully prepared in moderate to good yields from aromatic amines **2j–l** in the presence of 1,8-diazabicyclo[5.4.0]undec-7-ene (Table 2, entries 10–12). The yields of *N*,*N*′-diphenylureas **1j–m** were strongly affected by the basicity of anilines **2j–m**. 4-Methoxyaniline (**2k**), a basic aniline with an electron-donating group, gave urea **1k** in good yield (Table 2, entry 11). But 3-nitroaniline (**2m**), with an electron-withdrawing group, did not form *N*,*N*′-di(3-nitrophenyl)urea (**1m**) (Table 2, entry 13). We also examined the synthesis of urea derivatives **1n** and **1o** from secondary amines **2n** and **2o** (Table 2, entries 14 and 15). Ureas **1n** and **1o** did not form by this method. Under similar reaction conditions, *S*-alkyl *N*,*N*-dialkylthiocarbamates were obtained by esterification of *N*,*N*-dialkylthiocarbamate salts with alkyl halides.[27] Therefore, the oxidation reaction did not take place.

In this reaction system, sulfur was recovered from the resulting solution. We also tried using a catalytic amount of sulfur to prepare *N*,*N*′-dibenzylurea (**1i**). Benzylamine (**2i**) was mixed with 0.1 equivalents sulfur under a carbon monoxide–oxygen atmosphere (CO–O_2, 10:1) at 20 °C for 24 hours (Scheme 3). However, *N*,*N*′-dibenzylurea (**1i**) was not obtained at all, because of insufficient oxidation under a 10:1 CO–O_2 atmosphere. Next, the preparation of *N*,*N*′-dibenzylurea (**1i**) from benzylamine (**2i**) in the presence of 0.5 equivalent sulfur and two carbonylation–oxidation cycles was examined (Scheme 4). This gave urea **1i** in less than 50% yield. Therefore, the synthesis of urea derivatives **1** by this method can not be carried out with only catalytic amounts of sulfur.

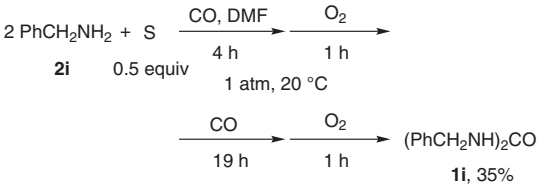


Scheme 3 Attempted synthesis of *N*,*N*′-dibenzylurea in the presence of a catalytic amount of sulfur

Table 2 Synthesis of Urea Derivatives from the Corresponding Amines

Entry	R^1	R^2	Amine	Urea	Yield (%)[a]
1	*c*-Hex	H	**2a**	**1a**	88
2	Bu	H	**2b**	**1b**	92
3	*s*-Bu	H	**2c**	**1c**	98
4	*t*-Bu	H	**2d**	**1d**	59
5	$(CH_2)_5Me$	H	**2e**	**1e**	88
6	$(CH_2)_6Me$	H	**2f**	**1f**	78
7	$(CH_2)_7Me$	H	**2g**	**1g**	91
8	$(CH_2)_9Me$	H	**2h**	**1h**	89
9	Bn	H	**2i**	**1i**	94
10	Ph	H	**2j**	**1j**	51[b]
11	4-$MeOC_6H_4$	H	**2k**	**1k**	84[b]
12	4-*i*-PrC_6H_4	H	**2l**	**1l**	49[b]
13	3-$O_2NC_6H_4$	H	**2m**	**1m**	0[b]
14	$-(CH_2)_5-$		**2n**	**1n**	0
15	Pr	Pr	**2o**	**1o**	0

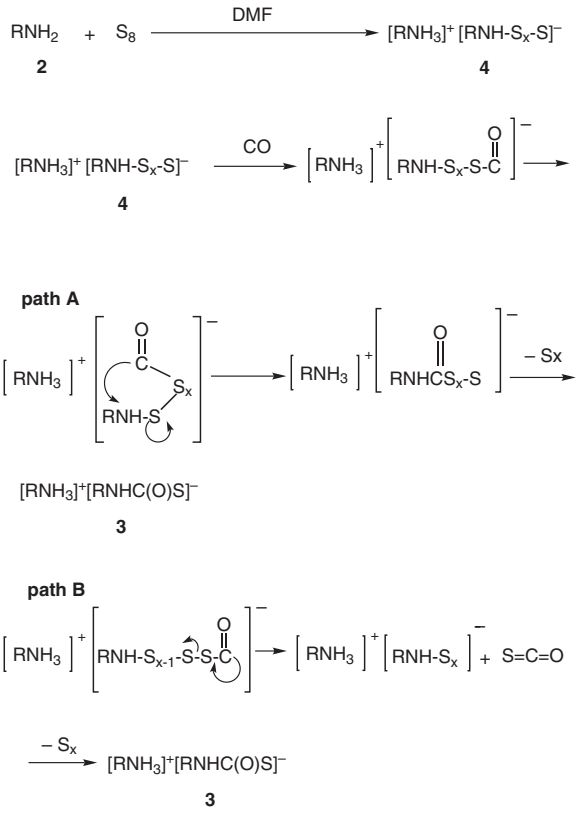
[a] Reagents and conditions: amine **2** (25 mmol), sulfur (321 mg, 10 mmol), DMF (20 mL), CO (1 atm), O_2 (1 atm), 20 °C, 5 h.
[b] DBU (1.50 mL, 10 mmol) was added; no reaction without DBU.



Scheme 4 Synthesis of *N*,*N*′-dibenzylurea in the presence of 0.5 equivalent sulfur

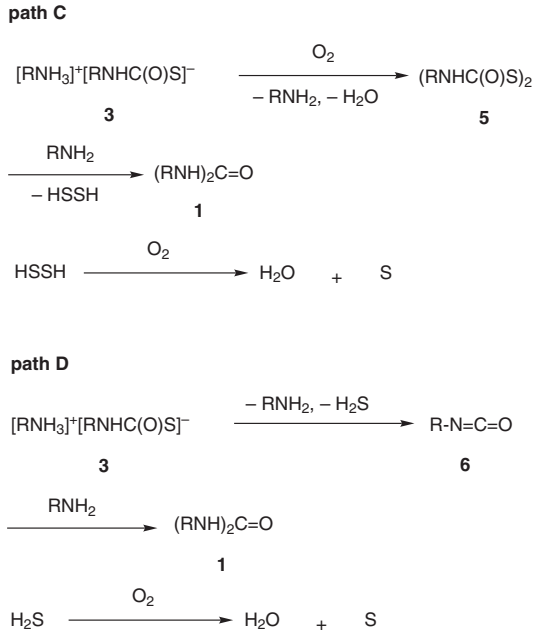
Schemes 5 and 6 show possible pathways for the synthesis of urea derivatives **1** by the carbonylation of amines **2** followed by oxidation of thiocarbamates **3**. We have found that thiolate salts **4** readily react with carbon monoxide to give thiocarbamate salts **3** (Scheme 5),[28] and therefore propose that a plausible pathway for this solvent-assisted carbonylation of amines **2** with carbon monoxide and sulfur is via thiolate anions **4**. At the stage where amines **2** are carbonylated, elemental sulfur undergoes S–S bond fission by the reaction with amines, with substantial assistance from *N*,*N*-dimethylformamide, to form ammonium thiolates **4**. The reaction of thiolate anions **4** with carbon monoxide gives the carbonylated species. Through an intramolecular rearrangement of the carbonylated species (Scheme 5, path A) or elimination of carbonyl sulfide from the carbonylated species (Scheme 5, path B), thiocarbamate salts **3** are generated. The thus formed thiocarbamate salts **3** are oxidized by molecular oxygen (Scheme 6), giving urea derivatives **1** via carbamoyl disulfides **5** (path C) or by an alternative pathway, via isocyanate intermediates **6** (path D). Path D via isocyanate intermediates **6** is supported by the fact that oxidation of secondary amines did not proceed at all.[29]

A useful synthetic method has been developed to provide urea derivatives **1** in good to excellent yields, under mild conditions (1 atm, 20 °C) in *N*,*N*-dimethylformamide, and involves the solvent-assisted carbonylation of amines by carbon monoxide and sulfur and the oxidation of the resulting thiocarbamate salts by molecular oxygen. In view of the application in the practical production of urea derivatives **1**, this method is very significant because easily available and cheap carbon monoxide, oxygen, sulfur, and *N*,*N*-dimethylformamide are used, and mild reaction conditions (1 atm, 20 °C) are required.



Scheme 5 Proposed pathway for the synthesis of thiocarbamate salts as intermediates in the synthesis of urea derivatives from the corresponding amines

Melting points were determined on a Mettler FP 5 instrument and are uncorrected. FT-IR spectra were recorded on a JASCO FT/IR-4100 instrument. ^1H and ^{13}C NMR spectra were obtained on a JEOL JNM-AL300 (300 MHz, 75 MHz) instrument. Chemical shifts δ are reported in ppm relative to tetramethylsilane. Both low- and high-resolution mass spectra were measured on a JEOL JMS-600 spectrometer. Amines **2a**–**o**, DMF, DMSO, THF, DBU, sulfur (99.5%), CO (99.9%), and O_2 (99.9%) were used as purchased.



Scheme 6 Proposed pathway for the synthesis of urea derivatives from the corresponding thiocarbamate salts

N,*N*′-Dicyclohexylurea (1a); Typical Procedure

A dark-red soln containing cyclohexylamine (**2a**; 2.86 mL, 25 mmol) and powdered sulfur (321 mg, 10 mmol) in DMF (20 mL) was vigorously stirred under CO (1 atm) at 20 °C for 4 h. Into the resulting pale-green emulsion of thiocarbamate salt **3a**, O_2 (1 atm) was charged at 20 °C (exothermic reaction). The mixture was stirred for an additional 1 h at 20 °C. The resulting pale-yellow emulsion was then poured into 1 M HCl (100 mL), and the deposited white solid was washed with toluene (200 mL) to give pure **1a**.

Yield: 1.96 g (88%); mp 231.7 °C (Lit.[22] 229–230 °C).

IR (KBr): 3327, 2928, 2850, 1627, 1576, 1311, 1244, 1089 cm^{-1}.

^1H NMR (300 MHz, DMSO-d_6): δ = 0.99–1.32 (m, 10 H, 5 × CH_2), 1.47–1.75 (m, 10 H, 5 × CH_2), 3.28–3.40 (m, 2 H, 2 × CH), 5.49 (d, *J* = 8.1 Hz, 2 H, 2 × NH).

^{13}C NMR (75 MHz, DMSO-d_6): δ = 24.2, 25.1, 33.1, 47.3, 156.5.

MS (EI, 70 eV): *m*/*z* (%) = 224 (80) [M^+], 143 (46), 99 (65), 56 (100).

HRMS (EI, 70 eV): *m*/*z* calcd for $C_{13}H_{24}ON_2$: 224.1889; found: 224.1886.

N,*N*′-Dibutylurea (1b)

Recrystallized from hexane.

Yield: 1.58 g (92%); mp 67.8 °C (Lit.[22] 67–69 °C).

IR (KBr): 3330, 2958, 2933, 2871, 1620, 1577, 1460, 1233 cm^{-1}.

^1H NMR (300 MHz, $CDCl_3$): δ = 0.91 (t, *J* = 7.2 Hz, 6 H, 2 × CH_3), 1.30–1.50 (m, 8 H, 4 × CH_2), 3.14 (q, *J* = 6.4 Hz, 4 H, 2 × CH_2), 5.56 (br s, 2 H, 2 × NH).

^{13}C NMR (75 MHz, $CDCl_3$): δ = 13.7, 20.0, 32.5, 39.9, 159.3.

MS (EI, 70 eV): *m*/*z* (%) = 172 (100) [M^+], 130 (17), 101 (16), 57 (13).

HRMS (EI, 70 eV): *m*/*z* calcd for $C_9H_{20}ON_2$: 172.1576; found: 172.1572.

N,*N*′-Di-*sec*-butylurea (1c)

Recrystallized from hexane.

Yield: 1.68 g (98%); mp 134.8 °C (Lit.[22] 135 °C).

IR (KBr): 3331, 2963, 2926, 2875, 1627, 1577, 1451, 1274 cm^{-1}.

^1H NMR (300 MHz, $CDCl_3$): δ = 0.91 (t, *J* = 7.3 Hz, 6 H, 2 × CH_3), 1.11 (d, *J* = 6.6 Hz, 6 H, 2 × CH_3), 1.39–1.49 (m, 4 H, 2 × CH_2), 3.61–3.70 (m, 2 H, 2 × CH), 4.33 (br s, 2 H, 2 × NH).

^{13}C NMR (75 MHz, $CDCl_3$): δ = 10.3, 21.0, 30.3, 47.3, 157.5.

MS (EI, 70 eV): *m*/*z* (%) = 172 (60) [M^+], 143 (100), 72 (35), 58 (88).

HRMS (EI, 70 eV): *m*/*z* calcd for $C_9H_{20}ON_2$: 172.1576; found: 172.1576.

N,*N*′-Di-*tert*-butylurea (1d)

Washed with toluene.

Yield: 1.01 g (59%); mp 242.9 °C (sublimed) (Lit.[22] 245 °C).

IR (KBr): 3356, 2965, 1637, 1560, 1361, 1209 cm^{-1}.

^1H NMR (300 MHz, DMSO-d_6): δ = 1.18 (s, 18 H, 6 × CH_3), 5.31 (br s, 2 H, 2 × NH).

^{13}C NMR (75 MHz, DMSO-d_6): δ = 29.3, 48.7, 157.0.

MS (EI, 70 eV): *m*/*z* (%) = 172 (7) [M^+], 157 (13), 58 (100), 57 (22).

HRMS (EI, 70 eV): *m*/*z* calcd for $C_9H_{20}ON_2$: 172.1576; found: 172.1574.

N,*N*′-Dihexylurea (1e)

Purified by short-column chromatography (silica gel, EtOAc).

Yield: 2.00 g (88%); mp 76.1 °C (Lit.[22] 73–74 °C).

IR (KBr): 3332, 2957, 2931, 2856, 1617, 1577, 1478, 1462, 1251, 1222 cm^{-1}.

^1H NMR (300 MHz, $CDCl_3$): δ = 0.88 (t, *J* = 6.0 Hz, 6 H, 2 × CH_3), 1.28–1.35 (m, 12 H, 6 × CH_2), 1.43–1.50 (m, 4 H, 2 × CH_2), 3.11–3.17 (m, 4 H, 2 × CH_2), 4.63 (br s, 2 H, 2 × NH).

^{13}C NMR (75 MHz, $CDCl_3$): δ = 14.0, 22.6, 26.6, 30.3, 31.5, 40.5, 158.5.

MS (EI, 70 eV): *m*/*z* (%) = 228 (100) [M^+], 199 (45), 185 (51), 158 (33).

HRMS (EI, 70 eV): *m*/*z* calcd for $C_{13}H_{28}ON_2$: 228.2202; found: 228.2198.

N,*N*′-Diheptylurea (1f)

Recrystallized from MeOH.

Yield: 2.00 g (78%); mp 91.2 °C.

IR (KBr): 3335, 2955, 2928, 2854, 1617, 1578, 1478, 1465 cm^{-1}.

^1H NMR (300 MHz, DMSO-d_6): δ = 0.86 (t, *J* = 6.8 Hz, 6 H, 2 × CH_3), 1.24–1.39 (m, 20 H, 10 × CH_2), 2.95 (t, *J* = 6.6 Hz, 4 H, 2 × CH_2), 5.42 (br s, 2 H, 2 × NH).

^{13}C NMR (75 MHz, DMSO-d_6): δ = 13.6, 21.8, 26.1, 28.2, 29.8, 31.0, 39.1, 157.9.

MS (EI, 70 eV): *m*/*z* (%) = 256 (100) [M^+], 213 (45), 199 (39), 172 (29).

HRMS (EI, 70 eV): *m*/*z* calcd for $C_{15}H_{32}ON_2$: 256.2515; found: 256.2518.

Anal. Calcd for $C_{15}H_{32}ON_2$: C, 70.26; H, 12.58; N, 10.92. Found: C, 70.34; H, 12.65; N, 11.08.

N,*N*′-Dioctylurea (1g)

Recrystallized from MeOH.

Yield: 2.57 g (91%); mp 91.0 °C (Lit.[22] 89–90 °C).

IR (KBr): 3334, 2956, 2925, 2850, 1615, 1579, 1478, 1463 cm^{-1}.

^1H NMR (300 MHz, DMSO-d_6): δ = 0.85 (t, J = 6.6 Hz, 6 H, 2 × CH_3), 1.23–1.34 (m, 24 H, 12 × CH_2), 2.93 (t, J = 6.8 Hz, 4 H, 2 × CH_2), 5.60 (br s, 2 H, 2 × NH).

^{13}C NMR (75 MHz, DMSO-d_6): δ = 13.6, 21.8, 26.1, 28.4, 28.5, 29.8, 31.0, 39.1, 157.9.

MS (EI, 70 eV): m/z (%) = 284 (100) [M^+], 241 (25), 227 (35), 213 (33), 186 (23), 57 (25).

HRMS (EI, 70 eV): m/z calcd for $C_{17}H_{36}ON_2$: 284.2828; found: 284.2816.

***N*,*N*′-Didecylurea (1h)[30]**
Recrystallized from MeOH.

Yield: 3.03 g (89%); mp 101.1 °C (Lit.[22] 99–100 °C).

IR (KBr): 3336, 2956, 2924, 2849, 1612, 1578, 1476, 1466 cm^{-1}.

MS (EI, 70 eV): m/z (%) = 340 (100) [M^+], 297 (24), 283 (18), 255 (30), 241 (28), 214 (19).

HRMS (EI, 70 eV): m/z calcd for $C_{21}H_{44}ON_2$: 340.3454; found: 340.3431.

***N*,*N*′-Dibenzylurea (1i)**
Washed with toluene.

Yield: 2.26 g (94%); mp 169.4 °C (Lit.[22] 169–171 °C).

IR (KBr): 3323, 3031, 1628, 1573, 1453, 1248, 696 cm^{-1}.

^1H NMR (300 MHz, DMSO-d_6): δ = 4.23 (s, 4 H, 2 × CH_2), 6.42 (br s, 2 H, 2 × NH), 7.18–7.33 (m, 10 H, 10 × CH).

^{13}C NMR (75 MHz, DMSO-d_6): δ = 42.9, 126.5, 126.9, 128.1, 140.8, 158.0.

MS (EI, 70 eV): m/z (%) = 240 (82) [M^+], 149 (31), 106 (100), 91 (63).

HRMS (EI, 70 eV): m/z calcd for $C_{15}H_{16}ON_2$: 240.1263; found: 240.1259.

***N*,*N*′-Diphenylurea (1j)**
Washed with toluene.

Yield: 1.08 g (51%); mp 241.0 °C (Lit.[31] 241–242 °C).

IR (KBr): 3327, 1649, 1595, 1556, 1233, 754, 698 cm^{-1}.

^1H NMR (300 MHz, DMSO-d_6): δ = 6.95 (t, J = 7.6 Hz, 2 H, 2 × CH), 7.27 (t, J = 7.6 Hz, 4 H, 4 × CH), 7.44 (d, J = 7.6 Hz, 4 H, 4 × CH), 8.67 (s, 2 H, 2 × NH).

^{13}C NMR (75 MHz, DMSO-d_6): δ = 118.1, 121.7, 128.7, 139.7, 152.5.

MS (EI, 70 eV): m/z (%) = 212 (36) [M^+], 119 (12), 93 (100).

HRMS (EI, 70 eV): m/z calcd for $C_{13}H_{12}ON_2$: 212.0950; found: 212.0903.

***N*,*N*′-Bis(4-methoxyphenyl)urea (1k)**
Washed with toluene and *t*-BuOMe.

Yield: 2.30 g (84%); mp 232.4 °C (Lit.[23] 232–234 °C).

IR (KBr): 3303, 1633, 1608, 1560, 1511, 1246, 827 cm^{-1}.

^1H NMR (300 MHz, DMSO-d_6): δ = 3.70 (s, 6 H, 2 × CH_3), 6.84 (d, J = 9.0 Hz, 4 H, 4 × CH), 7.33 (d, J = 9.0 Hz, 4 H, 4 × CH), 8.41 (br s, 2 H, 2 × NH).

^{13}C NMR (75 MHz, DMSO-d_6): δ = 55.1, 113.9, 119.8, 132.9, 152.9, 154.3.

MS (EI, 70 eV): m/z (%) = 272 (29) [M^+], 123 (58), 122 (100), 108 (62), 80 (32), 69 (39).

HRMS (EI, 70 eV): m/z calcd for $C_{15}H_{16}O_3N_2$: 272.1161; found: 272.1154.

***N*,*N*′-Bis(4-isopropylphenyl)urea (1l)**
Recrystallized from MeOH.

Yield: 1.46 g (49%); mp 238.4 °C.

IR (KBr): 3314, 2959, 1648, 1598, 1553, 1514, 1309, 1235 cm^{-1}.

^1H NMR (300 MHz, DMSO-d_6): δ = 1.17 (d, J = 7.2 Hz, 12 H, 4 × CH_3), 2.77–2.86 (m, 2 H, 2 × CH), 7.12 (d, J = 8.2 Hz, 4 H, 4 × CH), 7.34 (d, J = 8.2 Hz, 4 H, 4 × CH), 8.53 (s, 2 H, 2 × NH).

^{13}C NMR (75 MHz, DMSO-d_6): δ = 24.0, 32.7, 118.2, 126.4, 137.5, 141.7, 152.6.

MS (EI, 70 eV): m/z (%) = 296 (30) [M^+], 135 (26), 120 (100), 91 (30).

HRMS (EI, 70 eV): m/z calcd for $C_{19}H_{24}ON_2$: 296.1889; found: 296.1886.

Anal. Calcd for $C_{19}H_{24}ON_2$: C, 76.99; H, 8.16; N, 9.45. Found: C, 76.70; H, 8.09; N, 9.55.

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