Pergamon

Tetrahedron 55 (1999) 4843–4852

TETRAHEDRON

1-*tert*-Butoxycarbonyl-1-tosyl-hydrazine as Reagent for the Synthesis of Substituted Hydrazines with a Secondary Alkyl Group

Leif Grehn and Ulf Ragnarsson*

Department of Biochemistry, University of Uppsala, Biomedical Center, PO Box 576, SE-751 23 Uppsala, Sweden

Telephone: +46 (18) 4714555; Fax: +46 (18) 552139; E-mail: urbki@bmc.uu.se

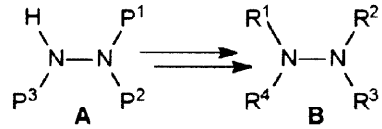
Received 8 January 1999; revised 27 January 1999; accepted 11 February 1999

Abstract: Catalytic hydrogenolysis of 1-Boc-1-Ts-2-Z-hydrazine furnished 1-Boc-1-Ts-hydrazine as a stable crystalline solid. Although its nucleophilicity is considerably suppressed in comparison with that of non- or monoacylated hydrazines, it reacted under various conditions with a representative set of ketones to give the corresponding hydrazones in high yields. The aliphatic hydrazones were readily reduced to hydrazines with $NaBH_4$, whereas the aromatic analogues for smooth reduction required the more powerful $NaBH_3CN$. With one exception all the new compounds were crystalline and stable under normal conditions. The new reagent and an alkylated derivative retained satisfactory reactivity towards activated isocyanates to provide acyl ureas. Some characteristic features of the NMR- and IR-spectra of these novel compounds are briefly discussed.

Keywords: Alkylation; Hydrazines; Protecting groups; Sulfonamides.

INTRODUCTION

Until recently the controlled substitution including alkylation of hydrazine was a difficult task,[1,2] as a result of which relatively few multisubstituted derivatives had been prepared. With the introduction of reagents carrying three orthogonal protecting groups P^1-P^3 **(A)**,[3] which in principle allow the stepwise introduction of up to four substituents R^1-R^4 **(B)**, a more rational approach to the synthesis and subsequent utilization of such



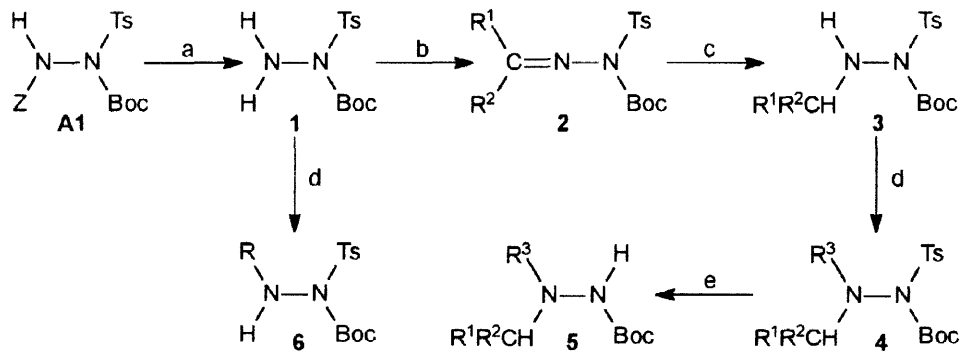
compounds was created. These reagents are now under investigation in our laboratory. Among those is **A1** (P^1=Ts, P^2=Boc=*tert*-butyloxycarbonyl and P^3=Z=benzyloxycarbonyl), the alkylation of which was carried out under phase-transfer catalysis (PTC) conditions.[4] This methodology worked well for primary and benzylic halides R^1X but studies with secondary reagents have been unsuccessful to date, the desired reactions taking place too slowly or not at all under such conditions. In order to widen the scope of this reagent, some additional

0040-4020/99/$ - see front matter
PII: S0040-4020(99)00156-8

work has consequently been carried out, as a result of which secondary alkyl groups can now also be attached onto one of its nitrogens.

Reduction of substituted hydrazones made from aldehydes and ketones is a relatively well-established procedure for making alkylated hydrazines. Recent examples include simple Boc-hydrazones.[5] Tosylhydrazones have also found many interesting applications, although their reduction generally leads to elimination of hydrazine and formation of the corresponding hydrocarbons.[6] To the best of our knowledge no *N,N*-diprotected hydrazine with two orthogonal, practically useful protective groups has been prepared so far. Therefore, we decided to exploit the stability of both Boc and Ts to catalytic hydrogenolysis and make an attempt to cleave the Z-group from **A1** in this way. This worked as planned and we obtained **1** in high yield. More importantly, the product turned out to be a stable reagent which reacted with ketones as required to allow the preparation of intermediates for polysubstituted hydrazines (Scheme 1).

Scheme 1: Preparation of hydrazine derivatives with secondary alkyl substituents.



2a, 3a: $R^1=R^2$=Me; **2b, 3b:** $R^1=R^2=-(CH_2)_5-$; **2c, 3c:** $R^1=R^2$=Bn; **2d, 3d:** R^1=Me, R^2=Ph; **2e, 3e:** $R^1=R^2$=Ph; **4, 5:** $R^1=R^2=-(CH_2)_5-$; **4a:** R^3=Ac; **4b:** R^3=TsNHCO; **4c:** R^3=BzNHCO; **5:** R^3=Ac; **6a:** R=TsNHCO; **6b:** R=BzNHCO; **6c:** R=BnNHCO

(a) H_2/5% Pd on carbon, MeOH (81%); (b) neat acetone (**2a**; 81%); *cyclo*hexanone, Et_2O (**2b**; 94%); Bn_2CO/PhCOMe/PhCOPh, boiling benzene (**2c-e**; 90%/81%/51%); (c) $NaBH_4$, THF/EtOH 2:1 (**3a,b**; 91%/90%); $NaBH_3CN$, THF/MeOH 10:1 (**3c-e**; 100%/92%/91%); (d) neat Ac_2O (**4a**; 91%), TsNCO/BzNCO, CH_2Cl_2 (**4b,c**; 97%/92%, **6a,b**; 91%/96%), BnNCO, boiling benzene (**6c**; 96%); (e) Mg, MeOH (**5**; 99%).

RESULTS AND DISCUSSION

Compound **1** was reacted with five typical ketones, acetone, *cyclo*hexanone, dibenzyl ketone, aceto- and benzophenone. At room temperature hydrazone formation was slow for the first two ketones and required days to go to completion, whereas the others did not react at all and required refluxing benzene to undergo con-

version. Reduction of the hydrazones **2a** and **2b** to the corresponding alkylhydrazines **3a** and **3b** was readily accomplished in excellent yields by $NaBH_4$ using THF/EtOH 2:1 as reaction medium. The analogous conversion of **2c** by the same method, however, failed and no trace of the desired **3c** could be detected. Also attempts to hydrogenate **2b** failed to produce detectable amounts of **3b**. However, in THF/MeOH 10:1 the $NaBH_3CN$-mediated reduction of **2c-e** with carefully controlled addition of dilute hydrochloric acid[7] provided **3c-e** in excellent yields.

Having established the reactivity of **1** towards ketones and elaborated proper conditions for its practical exploitation, in order also to make ureas,[8] we proceeded and reacted it with some activated isocyanates. Tosyl and benzoyl isocyanate both required at least a couple of hours to react completely with **1**, whereas in the case of benzyl isocyanate refluxing benzene was needed to give the corresponding substituted urea (semicarbazide) **6c**. These experiments were followed up by reaction of the *N-cyclo*hexyl derivative **3b** with tosyl and benzoyl isocyanate under similar conditions to give **4b** and **4c**, respectively, in excellent yields. From one compound, **4a**, cleavage of the tosyl group was attempted which would constitute a crucial step in the exploitition of *N,N*-disubstituted hydrazine derivatives of this type. For this purpose we could make use of the recently described mild reductive procedure, involving magnesium powder in anhydrous methanol,[9] which gave **5** in quantitative yield. A preliminary small scale experiment confirmed that **5** was readily and completely benzylated with benzyl bromide under PTC conditions according to a previous procedure for a similar substrate.[8] The resulting benzyl derivative of **5** should, after acidolysis, undergo normal acylations and thus give rise to a fully substituted hydrazine derivative.

As cyclic voltammetry has provided evidence for interaction of Boc- and tosyl- and similar protecting groups, when present on the same nitrogen atom,[10] a brief discussion of the spectral features of the compounds made would appear relevant at this stage. Previous observations have shown that, in $CDCl_3$, the Boc ^{13}C resonances are shifted in a characteristic manner when a Boc-NH moiety is converted to the corresponding BocTsN function.[4] Thus the CO resonance in the latter group is shifted about 5 ppm upfield (from $154 < \delta_{CO} < 155$ to $149 < \delta_{CO} < 150$ ppm) in comparison with the former moiety. On the other hand, the corresponding quartenary carbon in the Boc group undergoes the reverse shift downfield by about 3 ppm (from $81 < \delta_{Cq} < 82$ to $84 < \delta_{Cq} < 85$ ppm). These shifts were even larger when compound **1** was compared with the untosylated Boc-$NHNH_2$ (~6 ppm upfield for δ_{CO} and ~4.5 ppm downfield for δ_{Cq}. For the latter compound: δ_{Cq}=80.46 ppm and δ_{CO}=158.07 ppm). As one would expect that the electron-withdrawing tosyl group should induce a downfield shift also in the carbonyl group, this opposite shift might indicate the presence of sterical strain in compounds **2** which is then at least partially relieved by the reduction to **3** as can be seen below (to $152 < \delta_{CO} < 153$). Finally we noticed that the ^{13}C- as well as the ^{1}H-signal for the Boc-CH_3 group in Boc-$NHNH_2$ were only insignificantly shifted on tosylation to give **1** ($\delta_{H(Me)}$=1.46 ppm and $\delta_{C(Me)}$=28.31 ppm for the reference). In other cases with a higher degree of substitution, however, upfield shifts as large as 0.4 ppm have been observed for

^{1}H-signals, whereas the corresponding ^{13}C-resonances were generally shifted less than 1 ppm[4] (*cf.* compounds **4a/5**, see Experimental).

The suppressed nucleophilicity of **1** in comparison with the more commonly employed monosubstituted analogues Boc-$NHNH_2$ and Ts-$NHNH_2$ is reflected in the ^{15}N NMR spectra. Whereas the δ_{NH2} for the latter compounds are 54.64 and 57.49 ppm, respectively, it is shifted downfield to 68.72 ppm for **1**. In addition, substantial structural effects, parallel to the former ones, are noticed for the shift of the second nitrogen, which are 99.58 and 115.74 ppm, respectively, for the references. This signal in **1** appears as far downfield as 159.48 ppm.

IR-bands at 1358-1336/1360-1300 and 1169-1152/1190-1130 cm^{-1} have been ascribed to antisymmetric and symmetric SO_2 vibrations of sulfonamides[11a,12] and such at 600-520 and 555-445 cm^{-1} to SO_2 scissoring and wagging.[12] Assignments in *N*-BocTs compounds are complicated due to symmetrical methyl hydrogen deformations around 1375 cm^{-1} and skeletal vibrations in the vicinity of 1170 cm^{-1}.[11b] Thus, Boc-$NHNH_2$ in KBr exhibits absorption at 1367 and 1174 with further relevant bands at 1695 and 591 cm^{-1}. A spectral comparison of **1** and Ts-$NHNH_2$/Ts-NH_2 with bands at 1307/1326 and 1156/1151 cm^{-1} indicates a significant shift only of the former. This is evident also for **2a-3d** (9 compounds), 8 of which absorb above 1346 and all in the range 1146-1151 cm^{-1}. Generally two strong bands of diagnostic value with potential relevance to SO_2 scissoring and wagging appear at 560±25 cm^{-1}. For all compounds **1-3d** the Boc-CO bands are shifted to higher frequency in comparison with that of Boc-$NHNH_2$, although in two cases (**3a** and **3b**) these shifts are of moderate size.

In summary, using compound **1**, we have been able to eliminate a shortcoming in our procedure based on reagent **A1**[4] and successfully introduce bulky secondary alkyl groups onto a hydrazine nitrogen *via* hydrazone formation and subsequent reduction. In addition, from one such product by acylation we prepared three model compounds **4**, similar to hydrazine intermediates previously reported.[8] Furthermore, Boc-facilitated removal of the tosyl protecting group from one of them produced a compound **5** with a free NH which in principle can be alkylated with primary or benzylic halides under phase-transfer conditions. The cleavage of its remaining protecting group can easily be accomplished by treatment with acid.

EXPERIMENTAL

The following TLC systems were used: (A) toluene/MeCN 2:1; (B) light petroleum (bp 40-65°C)/Et_2O 2:1 and (C) CH_2Cl_2/acetone/HOAc 40:10:1. When not otherwise stated, NMR data were collected in $CDCl_3$ with Me_4Si as internal standard. In several cases these revealed the presence of conformers, as a consequence of which TLC was essential to establish purity. ^{15}N NMR spectra were recorded at 40.4 MHz in ~20% solution and the shifts were given as δ ppm using δ_{HCONH2}=113.2 as reference. FT-IR spectra were recorded for KBr disks at 4 cm^{-1} resolution on a Mattson Polaris spectrometer equipped with software for conversion to % transmission and unbiased determination of position and intensity of bands; intensities for selected bands were characterized as w(eak), m(edium), s(trong) and v(ery) s(strong); strongest bands occasionally indicated by vs_1, vs_2 etc. Other experimental conditions were the same as those reported earlier.[4]

1-*tert*-Butoxycarbonyl-1-tosyl-hydrazine (1): 1-Boc-1-Ts-2-Z-hydrazine[4] (**A1**) (4.21 g, 10.0 mmol) was hydrogenolyzed in MeOH (100 mL) in the presence of 5% Pd/C (0.67 g) for 2 h. Evaporation gave a sticky foam which was dissolved in Et_2O and evaporated to dryness. The remaining still sticky material was redissolved in warm Et_2O (50 mL), filtered and concentrated to 15 mL. After keeping at -20°C overnight, 2.33 g (81%) of white material, pure by TLC (A, B), could be isolated (the mother liquor contained further impure product). An analytical sample was obtained as white tiny needles; mp 90.5-91°C (from Et_2O/light petroleum). ^1H NMR: δ=1.44 (s, 9 H, Boc-Me), 2.45 (s, 3 H, Ts-Me), 4.11 (br. s, 2 H, NH_2), 7.33 (d, *J*=8.2 Hz, 2H, $Ts_{3,5}$), 7.84 (d, *J*=8.4 Hz, 2H, $Ts_{2,6}$). ^{13}C NMR: δ=21.64 (Ts-Me), 27.91 (Boc-Me), 85.09 (C_q), 128.10 ($Ts_{3,5}$), 129.46 ($Ts_{2,6}$), 135.55 (Ts_4), 144.75 (Ts_1), 152.13 (CO). ^{15}N NMR: δ=68.72 (NH_2), 159.48 (N). IR: ν=3389 (s) and 3314 (w, Δ=75,[13] both NH_2), 1712 (vs_2, CO), 1640 (m, δNH_2), 1355 (vs_4) and 1153 (vs_1, both νSO_2), 569 (s) and 542 (s, one or both δSO_2) cm^{-1}.

Anal. Calcd for $C_{12}H_{18}N_2O_4S$ (286.34): C, 50.33; H, 6.34; N, 9.78. Found: C, 50.4; H, 6.5; N, 9.8.

1-*tert*-Butoxycarbonyl-1-tosyl acetone hydrazone (2a): Crude **1** (573 mg, 2.00 mmol) was dissolved in acetone (3 mL) with gentle heating. The resulting solution was kept at r.t. for 3 days in a sealed flask. Evaporation to dryness left a viscous oil which was taken up in lukewarm light petroleum (20 mL). After filtering, the solution was cooled to 0°C and seeded. The next day a first crop (462 mg) of white crystalline pure (A, B) product was collected. Concentration to ~5 mL and cooling to -20°C afforded a second crop (64 mg); total yield 81%; mp 81.5-82.5°C. ^1H NMR: δ=1.35 (s, 9 H, Boc-Me), 2.11 and 2.22 [2s, 2x3 H, $(CH_3)_2C=$], 2.43 (s, 3 H, Ts-Me), 7.32 (d, *J*=8.1 Hz, 2H, $Ts_{3,5}$), 7.92 (d, *J*=8.1 Hz, 2H, $Ts_{2,6}$). ^{13}C NMR: δ=20.17 and 25.01 [$(CH_3)_2C=$], 21.61 (Ts-Me), 27.75 (Boc-Me), 84.48 (C_q), 128.30 ($Ts_{3,5}$), 129.27 ($Ts_{2,6}$), 135.61 (Ts_4), 144.53 (Ts_1), 149.48 (CO), 182.17 (N=C). IR: ν=3437 (w, br, overtone), 1728 (vs_2, CO), 1648 (m, C=N), 1366 (vs_3) and 1150 (vs_4, both νSO_2), 584 (vs_1) and 545 (vs, one or both δSO_2) cm^{-1}.

Anal. Calcd for $C_{15}H_{22}N_2O_4S$ (326.41): C, 55.19; H, 6.79; N, 8.58. Found: C, 55.4; H, 6.6; N, 8.7.

1-*tert*-Butoxycarbonyl-1-tosyl cyclohexanone hydrazone (2b): Crude **1** (1.43 g, 5.00 mmol) was dissolved in warm dry Et_2O (20 mL) and *cyclo*hexanone (0.74 g, 7.50 mmol) was added with mixing. Traces of turbidity were removed by filtration, whereupon the clear filtrate was concentrated to ~5 mL by gentle heating. After 2 days at r.t., white shiny crystals appeared. The precipitation was completed at -20°C for a couple of days. The crystals were collected by filtration, rinsed with cold Et_2O and dried in high vacuo. The yield of chromatographically pure (A, B) **2b** was 1.72 g (94%); mp 144-145°C (decomp.). ^1H NMR: δ=1.36 (s, 9 H, Boc-Me), 1.67 (m, 2 H, c-hexyl$_4$), 1.76 and 1.84 (2m, 2x2H, c-hexyl$_{3,5}$), 2.43 (s, 3 H, Ts-Me), 2.52 and 2.55 (2 overlapping t, together 4 H, c-hexyl$_{2,6}$), 7.31 (d, *J*=8.2 Hz, 2H, $Ts_{3,5}$), 7.92 (d, *J*=8.2 Hz, 2H, $Ts_{2,6}$). ^{13}C NMR: δ=21.64 (Ts-Me), 25.57 (c-hexyl$_4$), 26.43 and 27.23 (c-hexyl$_{3,5}$), 27.83 (Boc-Me), 30.51 and 35.63 (c-hexyl$_{2,6}$), 84.30 (C_q), 128.35 ($Ts_{3,5}$), 129.29 ($Ts_{2,6}$), 135.71 (Ts_4), 144.45 (Ts_1), 149.69 (CO), 186.95 (N=C). IR: ν=3445 (w, br, overtone), 1732 (vs_2, CO), 1638 (m, C=N), 1368 (vs_4) and 1151 (vs_1, both νSO_2), 584 (vs_3) and 546 (vs, one or both δSO_2) cm^{-1}.

Anal. Calcd for $C_{18}H_{26}N_2O_4S$ (366.48): C, 58.99; H, 7.15; N, 7.64. Found: C, 58.9; H, 7.4; N, 7.7.

1-*tert*-Butoxycarbonyl-1-tosyl dibenzyl ketone hydrazone (2c): Recrystallized **1** (1.15 g, 4.00 mmol) and dibenzyl ketone (841 mg, 4.00 mmol) were refluxed in benzene (4 mL) with monitoring by TLC (B). After 4 h both the starting materials had essentially been consumed. The solvent was removed under reduced pressure and the residual syrup was thoroughly dried in high vacuo until it solidified. The cake was dissolved in dry warm Et_2O (40 mL) and the turbid solution was treated with decolourizing carbon. The pale yellow filtrate was diluted with warm light petroleum (50 mL) and the solution concentrated to half its volume. Upon standing overnight large pale crystals appeared. The product was collected by filtration, rinsed with cold light petroleum and dried in high vacuo to give 1.73 g (90%) of essentially pure (A, B) **2c**; white, lustrous crystals with mp 109.5-110.5°C (from Et_2O/light petroleum 1:2). ^1H NMR: δ=1.37 (s, 9 H, Boc-Me), 2.45 (s, 3 H, Ts-Me), 3.66 and 3.79 (2 s, 2x2 H, Bn-CH_2), 7.12-7.31 (compl.

sign., 10 H, 2xPh), 7.34 (d, J=8.1 Hz, 2 H $Ts_{3,5}$), 7.96 (d, J=8.2 Hz, 2 H, $Ts_{2,6}$). ^{13}C NMR: δ=21.71 (Ts-Me), 27.88 (Boc-Me), 37.37 and 42.05 (Bn-CH_2), 84.75 (C_q), 126.88, 126.93, 128.53, 128.67, 128.70, 129.34, 129.44, 129.74, 135.19, 135.35, 135.75 (Ar), 144.70 (Ts_1), 149.81 (CO), 183.89 (N=C). IR: ν=3452 (w, br, overtone), 1737 (vs_3, CO), 1632 (m, C=N), 1363 (vs_2) and 1146 (vs_1, both νSO_2), 581 (s) and 550 (s, one or both δSO_2) cm^{-1}.

Anal. Calcd for $C_{27}H_{30}N_2O_4S$ (478.58): C, 67.76; H, 6.32; N, 5.85. Found: C, 68.0; H, 6.4; N, 5.9.

1-*tert*-Butoxycarbonyl-1-tosyl acetophenone hydrazone (2d): Recrystallized **1** (286 mg, 1.00 mmol) and acetophenone (132 mg, 1.10 mmol), dissolved in benzene (2 mL), was refluxed for 1 h, when TLC indicated that the reaction was complete and the solvent was removed under reduced pressure. The remaining viscous oil was thoroughly dried in high vacuo, whereafter it was dissolved in light petroleum (5 mL) with gentle heating and left for a few days at -20°C. The white solid formed was collected by filtration, rinsed with cold solvent and dried. The yield of product, pure by TLC (B), was 314 mg (81%). White heavy crystals (from Et_2O/light petroleum 1:4 at -20°C; 20 mL) with mp 106.5-107.5°C. ^1H NMR: δ=1.38 (s, 9 H, Boc-Me), 2.44 (s, 3 H, Ts-Me), 2.48 (s, 2 H, =C-Me), 7.34 (d, J=8.1 Hz, 2 H, $Ts_{3,5}$), 7.41-7.50 (compl. sign.) and 7.89 (d, J~8 Hz, 3 H+2 H, Ph), 7.99 (d, J=8.2 Hz, 2 H, $Ts_{2,6}$). ^{13}C NMR: δ=17.43 (=C-Me), 21.66 (Ts-Me), 27.83 (Boc-Me), 84.61 (C_q), 127.53, 128.43, 128.52, 129.32, 131.20, 135.46, 136.78 (Ar), 144.65 (Ts_1), 149.38 (CO), 178.35 (N=C). IR: ν=3450 (w, br, overtone), 1728 (vs_2, CO), 1611 (w, C=N), 1378 (vs_3) or 1366 (vs) and 1150 (vs_1, both νSO_2), 591 (vs_4) and 541 (vs, one or both δSO_2) cm^{-1}.

Anal. Calcd for $C_{20}H_{24}N_2O_4S$ (388.48): C, 61.83; H, 6.23; N, 7.21. Found: C, 62.2; H, 6.3; N, 7.4.

1-*tert*-Butoxycarbonyl-1-tosyl benzophenone hydrazone (2e): Recrystallized **1** (573 mg, 2.00 mmol) and benzophenone (364 mg, 2.00 mmol), dissolved in benzene (5 mL), was refluxed for 3 h, when TLC (B) indicated minor amounts of starting materials together with increasing amounts of a sideproduct. The solvent was removed under reduced pressure and the solid residue was suspended in Et_2O (20 mL) and applied to a silica column packed in Et_2O/light petroleum 1:3. Slow elution first provided minor amounts of benzophenone, followed by **2e** (461 mg, 51%) as a crispy foam. White, fluffy crystals; mp 84.5-85.5°C (from light petroleum at -20°C; 50 mL/g). ^1H NMR: δ=1.23 (s, 9 H, Boc-Me), 2.45 (s, 3 H, Ts-Me), 7.33 (d, J=8.6 Hz, 2 H, $Ts_{3,5}$), 7.36-7.51 (compl. sign., 8 H) and 7.69 (pert. d, J~8 Hz, 2 H, 2xPh), 7.89 (d, J=8.4 Hz, 2 H, $Ts_{2,6}$). ^{13}C NMR: δ=21.70 (Ts-Me), 27.70 (Boc-Me), 84.32 (C_q), 127.94, 128.23, 128.55, 129.26, 129.37, 129.77, 131.66, 134.76, 135.66, 136.69 (Ar), 144.52 (Ts_1), 149.16 (CO), 179.38 (N=C). IR: ν=1727 (vs_3, CO), 1376 (vs_1) and 1148 (vs_2, both νSO_2), 574 (vs) and 535 (s, one or both δSO_2) cm^{-1}.

Anal. Calcd for $C_{25}H_{26}N_2O_4S$ (450.55): C, 66.64; H, 5.82; N, 6.22. Found: C, 66.8; H, 5.8; N, 6.2.

1-*tert*-Butoxycarbonyl-2-*iso*propyl-1-tosyl-hydrazine (3a): Recrystallized **2a** (329 mg, 1.01 mmol) was dissolved in THF/EtOH 2:1 (6 mL) under argon and the resulting clear solution was treated with $NaBH_4$ (95 mg, 2.50 mmol) in small portions with rapid stirring over 5 min, whereupon the reaction was left to proceed under stirring with monitoring by TLC (B). After 8 h essentially all starting material had been consumed. The reaction mixture was treated with 2M HOAc (3 mL) and after 10 min the clear solution was partitioned between Et_2O (50 mL) and 1M Na_2CO_3 (25 mL). The aq. phase was further extracted with Et_2O (10 mL), whereupon the combined extracts were washed twice with brine and dried (Na_2SO_4). Removal of the solvent left a syrup which was chromatographed on silica using system B as eluent. The pure (A, B) title compound was obtained as a white solid; yield 301 mg (91%). Recrystallization from light petroleum (40 mL/g) gave the analytical sample as tiny white needles with mp 83.5-84°C. ^1H NMR: δ=1.08 [d, J=6.4 Hz, 6 H, $(CH_3)_2CH$], 1.39 (s, 9 H, Boc-Me), 2.44 (s, 3 H, Ts-Me), 3.31 [m, J=6.3 Hz, $(CH_3)_2CH$], 4.45 (br s, 1 H, NH), 7.31 (d, J=8.5 Hz, 2 H, $Ts_{3,5}$), 7.82 (d, J=8.4 Hz, 2 H, $Ts_{2,6}$). ^{13}C NMR: δ=20.52 [$(CH_3)_2CH$], 21.62 (Ts-Me), 27.85 (Boc-Me), 51.86 [$(CH_3)_2CH$], 84.79 (C_q), 128.24 ($Ts_{3,5}$), 129.28 ($Ts_{2,6}$), 136.30 (Ts_4), 144.40 (Ts_1), 152.33 (CO). IR: ν=3351 (s, NH), 1708 (vs_2, CO), 1340 (vs) or 1317 (vs_4) and 1148 (vs_1, both νSO_2), 572 (m) and 540 (vs, one or both δSO_2) cm^{-1}.

Anal. Calcd for $C_{15}H_{24}N_2O_4S$ (328.42): C, 54.86; H, 7.37; N, 8.53. Found: C, 55.1; H, 7.5, N, 8.6.

1-*tert*-**Butoxycarbonyl-2-*cyclo*hexyl-1-tosyl-hydrazine (3b):** Prepared from **2b** by analogy with **3a**. The yield of crude pure (A, B) **3b** was 90%. The analytical specimen was obtained by column chromatography on silica using Et_2O/light petroleum 1:1 as eluent followed by crystallization from Et_2O/light petroleum 1:4 (10 mL/g); white soft crystals with mp 116.5-117.5°C. ^1H NMR: δ=1.18-1.30 and 1.55-1.84 (compl. sign., together ~10 H, c-hexyl$_{2,6}$), 1.39 (s, 9 H, Boc-Me), 2.44 (s, 3 H, Ts-Me), 2.94 (m, 2 H, N-CH), 4.18 (br sign., ~1 H, NH), 7.30 (d, J=8.1 Hz, 2 H, $Ts_{3,5}$), 7.81 (d, J=8.4 Hz, 2 H, $Ts_{2,6}$). ^{13}C NMR: δ=21.61 (Ts-Me), 24.48 (c-hexyl$_4$), 25.84 (c-hexyl$_{3,5}$), 27.86 (Boc-Me), 30.95 (c-hexyl$_{2,6}$), 59.45 (N-CH), 84.77 (C_q), 128.20 ($Ts_{3,5}$), 129.25 ($Ts_{2,6}$), 136.32 (Ts_4), 144.37 (Ts_1), 152.33 (CO). IR: ν=3328 (s, NH), 2927 (vs$_4$) and 2856 (s, both CH_2), 1703 (vs$_2$, CO), 1346 (vs$_1$) and 1150 (vs$_3$, both νSO_2), 574 (vs$_5$) and 540 (s, one or both δSO_2) cm^{-1}.
Anal. Calcd for $C_{18}H_{28}N_2O_4S$ (368.50): C, 58.67; H, 7.66; N, 7.60. Found: C, 58.9; H, 7.5; N, 7.8.

1-*tert*-Butoxycarbonyl-2-(1,3-diphenyl-2-propyl)-1-tosyl-hydrazine (3c): Recrystallized **2c** (319 mg, 0.67 mmol) in dry THF/MeOH 10:1 (3.3 mL) was cautiously treated with small portions of $NaBH_3CN$ (127 mg, 2.00 mmol) with rapid stirring under argon. A few grains of bromocresol green were introduced and to the resulting blue solution 2 M HCl was added with vigorous agitation at a rate just to maintain a yellow colour. After 3 h, when ~0.3 mL had been consumed and the colour persisted for over 30 min, the reaction was quenched by partition between Et_2O (30 mL) and 1M Na_2CO_3 (15 mL). The blue aq. phase was further extracted with Et_2O (10 mL) and the combined extracts were washed with brine and dried (Na_2SO_4). Removal of the solvent left a colourless viscous oil weighing 320 mg (quant.) after thorough drying, pure by ^1H and ^{13}C NMR. The crude product slowly solidified on trituration with cold light petroleum. White, shiny crystals (from Et_2O/light petroleum 1:10 at -20°C; 80 mL/g) with mp 109.5-110.5°C. ^1H NMR: δ=1.37 (s, 9 H, Boc-Me), 2.42 (s, 3 H, Ts-Me), 2.67 and 2.80 (ABq, J_1=13.9 Hz, further split by coupling to CH, J_2=6.9 Hz, 4 H, 2xCH_2), 3.71 (dp, J_1=6.9 Hz, J_2=3.1 Hz, 1 H, CH), 4.52 (d, J=3.4 Hz, 1 H, NH), 7.16-7.30 (compl. sign., 12 H, 2xPh + $Ts_{3,5}$), 7.68 (d, J=8.2 Hz, 2 H, $Ts_{2,6}$). ^{13}C NMR: δ=21.63 (Ts-Me), 27.87 (Boc-Me), 38.73 (CH_2), 62.20 (CH), 85.00 (C_q), 127.32, 128.34, 128.41, 129.30, 129.32, 135.73, 138.40 (Ar), 144.51 (Ts_1), 152.37 (CO). IR: ν=3287 (m, NH), 1725 (vs$_2$, CO), 1375 (vs$_1$) and 1151 (vs$_3$, both νSO_2), 580 (vs) and 552 (s, one or both δSO_2) cm^{-1}.
Anal. Calcd for $C_{27}H_{32}N_2O_4S$ (480.62): C, 67.47; H, 6.71; N, 5.83. Found: C, 68.0; H, 6.8; N, 6.0.

1-*tert*-Butoxycarbonyl-2-(1-phenylethyl)-1-tosyl-hydrazine (3d): Prepared by the $NaBH_3CN$-mediated reduction of **2d** by analogy with the procedure for **3c**. The yield on a similar scale of **3d** after chromatography on silica using Et_2O/light petroleum 1:3 as eluent was 92%. The resulting viscous oil slowly solidified on standing in the cold. The analytical sample was obtained as white tiny crystals from Et_2O/light petroleum 1:20 at -20°C (70 mL/g); mp 80.5-81°C. ^1H NMR: δ=1.34 (s, 9 H, Boc-Me), 1.42 (d, J=6.6 Hz, 3 H, CHCH_3), 2.41 (s, 3 H, Ts-Me), 4.30 (pert. m, J_1=6.7 Hz, J_2~2 Hz, 1 H, CHCH$_3$), 4.70 (pert. d, J~2 Hz, 1 H, NH), 7.24-7.41 (compl. sign., 7 H, Ph + $Ts_{3,5}$), 7.71 (br sign., 2 H, $Ts_{2,6}$). ^{13}C NMR: δ=20.13 (CHCH_3), 21.59 (Ts-Me), 27.77 (Boc-Me), 60.38 (CHCH$_3$), 84.70 (C_q), 127.72, 127.90, 128.24, 128.35, 129.21 (Ar), 136.33 (Ts_4), 141.89 (Ph_1), 144.33 (Ts_1), 152.08 (CO). IR: ν=3317 (s, NH), 1731/1722 (vs, CO), 1354 (vs) and 1147 (vs$_1$, both νSO_2), 573 (vs$_2$) and 540 (s, one or both δSO_2) cm^{-1}.
Anal. Calcd for $C_{20}H_{26}N_2O_4S$ (390.50): C, 61.51; H, 6.71; N, 7.17. Found: C, 61.6; H, 6.7; N, 7.1.

1-*tert*-Butoxycarbonyl-2-diphenylmethyl-1-tosyl-hydrazine (3e): Prepared by the $NaBH_3CN$-mediated reduction of **2e** by analogy with the procedure for **3c**. The yield of crude, chromatographically (B) pure **3e** was 90% on a 0.5 mmol scale. Attempts to crystallize the resulting oil from light petroleum failed. ^1H NMR: δ=1.29 (s, 9 H, Boc-Me), 2.38 (s, 3 H, Ts-Me), 5.10 (d, J=2.7 Hz, 1 H, CH), 5.42 (d, J=2.5 Hz, 1 H, NH), 7.17 (d, J=8.1 Hz, 2 H $Ts_{3,5}$), 7.23-7.32 (compl. sign., 6 H), 7.49 and 7.51 (overlapping d, together 6

H, Ar). ^{13}C NMR: δ=21.53 (Ts-Me), 27.68 (Boc-Me), 69.11 (CH), 84.73 (C_q), 127.67, 128.05, 128.35, 128.46, 129.13, 136.71, 140.23 (Ar), 144.15 (Ts_1), 151.90 (CO).

2-Acetyl-1-*tert*-butoxycarbonyl-2-*cyclo*hexyl-1-tosyl-hydrazine (4a): Recrystallized **3b** (553 mg, 1.50 mmol) in acetic anhydride (2 mL, ~14 eq) was heated to 80°C for 20 min, whereupon the excess anhydride was evaporated completely in vacuo at a bath temperature of 40°C. The remaining oil was partitioned between Et_2O (75 mL) and 1 M $KHSO_4$ (25 mL), the organic extract washed in turn with $KHSO_4$, 1 M $NaHCO_3$ and brine (3 times each) and dried ($MgSO_4$). Removal of the solvent left a pale yellow oil which was chromatographed on silica (B) to produce 562 mg (91%) of a pure (A, B) fraction as a sticky sirup which crystallized from Et_2O/light petroleum 1:8 at -20°C (30 mL/g); mp 86-86.5°C. ^{1}H NMR: major/minor conformer δ=1.01-2.23 (compl. overlapping sign., ~10 H, c-hexyl$_{2-6}$), 1.48/1.28 (2s, together 9 H, Boc-Me), 2.07/2.28 (2s, together 3 H, Ac-Me), 2.48/2.43 (2s, together 3 H, Ts-Me), 4.00/3.84 (2tt, J_1=11.6 Hz, J_2=3.7 Hz, together 1 H, N-CH), 7.37/7.29 (2d, J=8.2 Hz, together 2 H, $Ts_{3,5}$), 8.01/8.08 (2d, J=8.4 Hz, together 2 H, $Ts_{2,6}$). ^{13}C NMR: major/minor conformer δ=21.53/21.71/21.66 (Ts-Me + Ac-Me), 25.52/25.09/25.76/25.63, 25.94/25.88 (c-hexyl$_{3,4,5}$), 27.94/27.70 (Boc-Me), 28.44/30.51, 30.95/31.94 (c-hexyl$_{2,6}$), 60.25/61.98 (N-CH), 85.89/84.98 (C_q), 129.37/128.65 ($Ts_{3,5}$), 129.84/130.57 ($Ts_{2,6}$), 135.25/135.61 (Ts_4), 145.55/144.63 (Ts_1), 150.46/150.09 (Boc-CO) and 173.31/169.18 (Ac-CO). IR: ν~3474 (w, br, overtone), 1745 (vs_3, Boc-CO), 1687 (vs_2, Ac-CO), 1359 (vs_4) and 1149 (vs_1, both $νSO_2$), 591 (vs), 562 (s) and 540 (s, one or two of which $δSO_2$) cm^{-1}.

Anal. Calcd for $C_{20}H_{30}N_2O_5S$ (410.53): C, 58.51; H, 7.37; N, 6.82. Found: C, 58.8; H, 7.4; N, 6.9.

1-*tert*-Butoxycarbonyl-2-*cyclo*hexyl-1-tosyl-2-(*N*-tosylcarbamoyl)-hydrazine (4b): Recrystallized **3b** (368 mg, 1.00 mmol) in anhyd CH_2Cl_2 (2 mL) was treated dropwise with rapid stirring with TsNCO (200 mg, 1.00 mmol) in CH_2Cl_2 (2 mL) at 0°C under argon over 5 min and kept in a stoppered flask for 5 h at r.t., whereupon the solvent was removed under reduced pressure. The remaining crispy foam was carefully triturated with cold light petroleum and the insoluble white powder collected by filtration, rinsed repeatedly and dried in high vacuo; yield 551 mg (97%). TLC (A,C) and NMR revealed the presence of contaminating $TsNH_2$ which could not be readily removed by reprecipitation from Et_2O/light petroleum mixtures; mp 82-85°C (softens 70-80°C). ^{1}H NMR: δ=1.01-1.84 (compl. sign., 9 H) and 2.09 (pert. d, J=12.3 Hz, 1 H, c-hexyl$_{2-6}$), 1.42 (s, 9 H, Boc-Me), 2.44 and 2.49 (2s, 3 H each, Ts-Me), 3.88 (tt, J_1=11.6 Hz, J_2=3.8 Hz, 1 H, N-CH), 7.33 (d, J=8.1 Hz) and 7.40 (d, J=8.2 Hz, 2x2H, $Ts_{3,5}$), ~7.81 (br s, ~1 H, NH), 7.94 (d, J=8.4 Hz) and 7.97 (d, J=8.3 Hz, 2x2H, $Ts_{2,6}$). ^{13}C NMR: δ=21.64 and 21.80 (Ts-Me), 25.28, 25.48 and 25.61 (c-hexyl$_{3-5}$), 27.73 (Boc-Me), 29.14 and 30.96 (c-hexyl$_{2-6}$), 60.61 (N-CH), 87.01 (C_q), 128.43, 129.46, 129.72, 129.93, 134.23 (c-hexyl$_1$), 135.91 (Ar), 144.69 and 146.29 (Ts_1), 149.82 (Boc-CO), 150.88 (urea-CO). IR: ν=3404 (w, overtone), 3283 (w, br, NH), 1750 (s, Boc-CO), 1712 (s, urea-CO), 1360 (vs) and 1169 (vs_1, both $νSO_2$), 578 (vs), 556 (vs_3) and 547 (s, one or two of which $δSO_2$) cm^{-1}.

Anal. Calcd for $C_{26}H_{33}N_3O_7S_2$ (565.71): C, 55.20; H, 6.24; N, 7.43. Found: C, 55.3; H, 6.5; N, 7.3.

2-(*N*-Benzoylcarbamoyl-1-*tert*-butoxycarbonyl-2-*cyclo*hexyl-1-tosyl-hydrazine (4c): Prepared from **3b** and BzNCO as described for **4b**. A similar workup afforded pure (A, C) **4c** in 92% yield on a 0.5 mmol scale; mp 124-125°C (twice from CH_2Cl_2/Et_2O 1:10 at -20°C; 150 mL/g). ^{1}H NMR: δ=1.06-1.93 (compl. sign., 9 H) and 2.26 (pert. d, J=12.6 Hz, 1 H, c-hexyl$_{3-5}$), 1.42 (s, 9 H, Boc-Me), 2.42 (s, 3 H, Ts-Me), 4.03 (tt, J_1=11.7 Hz, J_2=3.7 Hz, 1 H, N-CH), 7.31 (d, J=8.2 Hz, 2 H, $Ts_{3,5}$), 7.42 (t, J=7.8 Hz, 2 H, $Bz_{3,5}$), 7.54 (t, J=7.5 Hz, 1 H, Bz_4), 7.74 (d, J=7.3 Hz, 2 H, $Bz_{2,6}$), 8.00 (d, J=8.4 Hz, 2 H, $Ts_{2,6}$), and 8.54 (br s, 1 H, NH). ^{13}C NMR: δ=21.71 (Ts-Me), 25.43, 25.57 and 25.73 (c-hexyl$_{3-5}$), 27.76 (Boc-Me), 29.13 and 31.05 (c-hexyl$_{2,6}$), 60.96 (N-CH), 86.84 (C_q), 127.55, 128.65, 129.60, 129.85, 132.59, 133.35, 134.23 (Ar), 146.16 (Ts_1), 150.21 (Boc-CO), 151.23 (urea-CO), 165.31 (Bz-CO). IR:

ν~3437 (w, br, overtone), 3195 (w, br, NH), 1748 (vs_2, Boc-CO), 1718 (vs, urea-CO), 1665 (vs, Bz-CO), 1366 (vs) and 1145 (vs_1, both νSO_2), 573 (vs_3) and 541 (m, one or both δSO_2) cm^{-1}.

Anal. Calcd for $C_{26}H_{33}N_3O_6S$ (515.62): C, 60.56; H, 6.45; N, 8.15. Found: C, 60.7; H, 6.4; N, 8.2.

1-Acetyl-2-*tert*-butoxycarbonyl-1-*cyclo*hexyl-hydrazine (5): Recrystallized **4a** (205 mg, 0.50 mmol) in anhyd MeOH (3 mL) was sonicated with magnesium powder (37 mg, 1.50 mmol) for 30 min at r.t. (frothing commenced within a few min and after 20 min essentially all Mg had been consumed). Most of the solvent was removed under reduced pressure and the residual greyish sludge was partitioned between Et_2O (25 mL) and 0.2 M citric acid (10 mL). The colourless organic extract was washed in turn with citric acid, 1 M $NaHCO_3$ and brine (3x5 mL each) and dried ($MgSO_4$). Removal of the solvent left a colourless oil (127 mg, 99%) which soon solidified on standing; pure by TLC (A). The analytical sample, obtained as soft white crystals by recrystallization from Et_2O/light petroleum 1:4 at -20°C (90 mL/g; seeding), exhibited mp 125-126°C (softens at ~95°C; if mp capillary is inserted above 96°C, rapid melting takes place followed by slow resolidification and final, complete melting as stated). ^1H NMR: δ=1.03-1.91 (compl. sign., 10 H, c-hexyl$_{2-6}$), 1.49 (s, 9 H, Boc-Me), 2.06/2.07/2.17 (3s, together 3 H, Ac-Me), 4.41/3.62 (2tt, J_1=11.5 Hz, J_2=3.7 Hz, together 1 H, N-CH), 6.64/6.68/6.19 (3 br sign., together 1 H, NH). ^{13}C NMR: δ=21.03/21.13/21.27 (Ac-Me), 25.40/25.36/25.52/25.08 (c-hexyl$_{3,4,5}$), 28.18/28.13 (Boc-Me), 29.50/29.54 and 29.77 (c-hexyl$_{2,6}$), 54.85/54.66/59.66 (c-hexyl N-CH), 81.49/82.32/81.23 (C_q), 154.65/155.30/156.44 (Boc-CO) and 172.79/172.59/169.57 (Ac-CO). IR: ν=3482 (w, br, CO-overtone), 3225 (s, NH), 1740 (vs_2, Boc-CO), 1632 (vs_1, Ac-CO), 1540 (m, amide II), 589 (w, strong peaks missing 1100-400) cm^{-1}.

Anal. Calcd for $C_{13}H_{24}N_2O_3$ (256.34): C, 60.91; H, 9.44; N, 10.93. Found: C, 61.4; H, 9.5; N, 11.0.

1-*tert*-Butoxycarbonyl-1-tosyl-2-(*N*-tosylcarbamoyl)-hydrazine (6a): Prepared from **1** and TsNCO as described for **4b**. Trituration of the evaporation residue with cold Et_2O and filtering afforded pure (A,C) **6a** in 91% yield on a 2 mmol scale. The analytical specimen (from CH_2Cl_2/Et_2O 1:6) was microcrystalline and had mp 154-155°C (decomp.). ^1H NMR (DMSO-d_6): δ=1.16 (s, 9 H, Boc-Me), 2.40 (s, 3 H, Ts-Me), 7.38 (d, J=8.2 Hz) and 7.44 (d, J=8.2 Hz, 2x2H, Ts$_{3,5}$), 7.77 (d, J=8.3 Hz) and 7.83 (d, J=8.3 Hz, 2x2H, Ts$_{2,6}$), 9.64 (s, 1 H, N-NH), 11.66 (br s, 1 H, Ts-NH). ^{13}C NMR (DMSO-d_6): δ=21.02 and 21.08 (Ts-Me), 27.20 (Boc-Me), 84.38 (C_q), 127.38 and 128.36 (Ts$_{3,5}$), 129.21 and 129.42 (Ts$_{2,6}$) , 135.67 and 137.01 (Ts$_4$), 143.90 and 144.66 (Ts$_1$), 149.29 (Boc-CO) and 150.97 (urea-CO). ^{15}N NMR (DMSO-d_6): δ=116.68, 140.75, 159.78 (w). IR: ν=3326 (s, NH), 1747 (vs, Boc-CO), 1697 (vs, urea-CO), 1354 (vs_1), 1163 (vs_2) and 1144 (vs, all νSO_2), 582 (vs), 565 (s) and 545 (m, one or two of which δSO_2) cm^{-1}.

Anal. Calcd for $C_{20}H_{25}N_3O_7S_2$ (483.57): C, 49.68; H, 5.21; N, 8.69. Found: C, 49.3; H, 5.2; N, 8.7.

2-(*N*-Benzoylcarbamoyl)-1-*tert*-butoxycarbonyl-1-tosyl-hydrazine (6b): Obtained from **1** and BzNCO by analogy with the method for **6a**. A 0.50 mmol run provided pure (A,C) **6b** in 96% yield; mp 168-170°C (decomp.; from CH_2Cl_2/Et_2O 1:5, 60 mL/g). ^1H NMR: δ=1.38 (s, 9 H, Boc-Me), 2.32 (s, 3 H, Ts-Me), 7.18 (d, J=8.1 Hz, 2 H, Ts$_{3,5}$), 7.33 (pert. t, J=8 Hz, 2 H, Bz$_{3,5}$), 7.53 (pert. t, J=8 Hz, 1 H, Bz$_4$), 7.97 (pert. t) and 7.98 (d, J=8 Hz, together 4 H, Bz$_{2,6}$ and Ts$_{2,6}$), 10.23 and 10.89 (2 br sign., 2x1 H, NH). ^{13}C NMR: δ=21.61 (Ts-Me), 27.85 (Boc-Me), 85.61 (C_q), 128.22, 128.88, 129.20, 129.25, 131.03, 133.36, 135.65 (Ar), 145.05 (Ts$_1$), 149.56 (Boc-CO), 154.79 (urea-CO) and 167.87 (Bz-CO). IR: ν=3262 (s, NH), 1761 (vs_5, Boc-CO), 1698 (vs_3, urea-CO), 1686 (vs_4, Bz-CO), 1368 (vs_1) and 1150 (vs_2, both νSO_2), 562 (s) and 539 (s, one or both δSO_2) cm^{-1}.

Anal. Calcd for $C_{20}H_{23}N_3O_6S$ (433.48): C, 55.42; H, 5.35; N, 9.69. Found: C, 55.6; H, 5.4; N, 9.7.

2-(*N*-Benzylcarbamoyl)-1-*tert*-butoxycarbonyl-1-tosyl-hydrazine (6c): A mixture of BnNCO (89 mg, 0.60 mmol) and **1** (143 mg, 0.50 mmol) in anhyd benzene (2 mL) was refluxed for 3 h. A white precipitate was formed which after a few hours was filtered off, rinsed with small portions of benzene and dried in vacuo, giving 201 mg (96%) of pure (A, C) **6c**; white tiny crystals with mp 165-

166°C (decomp.; from CH_2Cl_2/Et_2O 1:3, 80 mL/g). ^1H NMR: δ=1.36 (s, 9 H, Boc-Me), 2.40 (s, 3 H, Ts-Me), 4.36-4.46 (ABq, *J*=15 Hz, further split by coupling to NH, *J*=6 Hz, 2 H, CH_2), 5.81 (t, *J*=6 Hz, 1 H, Bn-NH), 7.21-7.32 (compl. sign., 7 H, Bn + $Ts_{3,5}$), 7.49 (br sign., 1 H, N-NH), 7.92 (d, *J*=8.4 Hz, 2 H, $Ts_{2,6}$). ^{13}C NMR: δ=21.69 (Ts-Me), 27.74 (Boc-Me), 44.03 (CH_2), 85.90 (C_q), 127.26, 127.28, 128.55, 128.92, 129.44, 134.70, 138.48 (Ar), 145.19 (Ts_1), 150.50 (Boc-CO) and 158.98 (urea-CO). IR: ν=3410 (s) and 3257 (s, both NH), 1745 (vs_2, Boc-CO), 1669 (vs_6, urea-CO), 1555 (s, amide II), 1368 (vs_1), 1172 (vs_3) and 1147 (vs_5, all νSO_2), 576 (vs) and 549 (s, one or both δSO_2) cm^{-1}.

Anal. Calcd for $C_{20}H_{25}N_3O_5S$ (419.50): C, 57.26; H, 6.01; N, 10.02. Found: C, 57.1; H, 6.0; N, 10.0.

ACKNOWLEDGEMENT

This work was supported by funds from the Swedish Research Council for Engineering Sciences and the Swedish Natural Science Research Council which are gratefully acknowledged.

REFERENCES

1. Jensen-Korte, U. In *Houben-Weyl,* 4th ed., Vol. 16a; Klamann, D., Ed.; Thieme: Stuttgart, 1990; p 421.
2. Brown, B.R. *The Organic Chemistry of Aliphatic Nitrogen Compounds;* Clarendon: Oxford, 1994; p 588.
3. Ragnarsson, U.; Grehn, L. *Acc. Chem. Res.* **1998**, *31*, 494-501 and references therein.
4. Grehn, L.; Nyasse, B.; Ragnarsson, U. *Synthesis* **1997**, 1429-1432.
5. a) Ghali, N.I.; Venton, D.L.; Hung, S.C.; Le Breton, G.C. *J. Org. Chem.* **1981**, *46*, 5413-5414. b) Calabretta, R.; Gallina, C.; Giordano, C. *Synthesis* **1991**, 536-539.
6. a) Chamberlin, A.R.; Sheppeck II, J.E. In *Encyclopedia of Reagents for Organic Synthesis,* Vol. 7; Paquette, L.A., Ed.; Wiley: Chichester, 1995; p 4953. b) Wu, P.-L.; Peng, S.-Y.; Magrath, J. *Synthesis* **1996**, 249-252.
7. Lawton, G.; Moody, C.J.; Pearson, C.J.; Williams, D.J. *J. Chem. Soc., Perkin Trans. 1* **1987**, 885-897.
8. Grehn, L.; Ragnarsson, U. *Synthesis* **1998**, 1817-1821.
9. Nyasse, B.; Grehn, L.; Ragnarsson, U. *Chem. Commun.* **1997**, 1017-1018.
10. Nyasse, B.; Grehn, L.; Ragnarsson, U.; Maia, H.L.S.; Monteiro, L.S.; Leito, I.; Koppel, I.; Koppel, J. *J. Chem. Soc., Perkin Trans. 1* **1995**, 2025 -2031 and references therein.
11. Bellamy, L.J. *The Infrared Spectra of Complex Molecules,* 3rd edition, Chapman and Hall, London 1975, (a) p 407; (b) p 14.
12. Roeges, N.P.G. *A Guide to the Complete Interpretation of Infrared Spectra of Organic Structures,* Wiley, Chichester 1994, p 295.
13. Blair, J.A.; Gardner, R.J. *J. Chem. Soc. (C)* **1970**, 2707-2708.