ω scans) reflections having $2\theta_{MoK\bar{\alpha}} < 55°$ and $I > 3\sigma(I)$] in cycles of empirically weighted least-squares refinement. Anisotropic thermal parameters were utilized for all nonhydrogen atoms and isotropic thermal parameters for all hydrogen atoms. The estimated standard deviations for covalent bond lengths are 0.002–0.003 Å for bonds between two nonhydrogen atoms and 0.02–0.03 Å for bonds between a hydrogen and nonhydrogen atom. Full structural details will be published elsewhere.

(14) The coupling and cross-coupling reactions of alkyl halides and Grignard reagents (sometimes called Kharasch couplings) have been the subject of considerable study during the past 10 years. A recent review of much of this chemistry with leading references to other aspects is (a) H. Felkin and G. Swierczewski, *Tetrahedron*, **31**, 2735 (1975). Additional pertinent references are (b) Y. Ohbe and T. Matsuda, *Nippon Kagaku Zasshi*, **89**, 298 (1968) [*Chem. Abstr.*, **69**, 51309q (1968)]; (c) Y. Ohbe and T. Matsuda, *Bull. Chem. Soc. Jpn.*, **45**, 2947 (1972); (d) Y. Ohbe and T. Matsuda, *Tetrahedron*, **29**, 2989 (1973); (e) Y. Ohbe, M. Takagi, and T. Matsuda, *ibid.*, **30**, 2669 (1974); (f) M. Mori, S. Nishimura, and Y. Ban, *Tetrahedron Lett.*, 4951 (1973).

(15) Talaty et al.[4] reported that the ^1H NMR spectrum of their crude product showed the presence of two substances, **2c** (X = I) being by far the more abundant. The second product was not identified.

(16) The question remains as to the probable identity of the well-characterized Sheehan–Nafissi-V product. Our experimental observations lead us to conclude that the product may have been an impure sample of the reduction product **8c**, possibly contaminated with **9cw** and the diastereomers of the dimeric coupling product **7c**. The contaminants are required to explain the observed ^1H NMR spectrum, elemental analysis, and mass spectrum.

(17) The first preparation of an authentic α-lactam [H. E. Baumgarten, *J. Am. Chem. Soc.*, **84**, 4975 (1962)] involved the cyclization of an *N*-chloro amide with potassium *tert*-butoxide as base. The choice of base was deliberate, based on sound experimental analogies. Later the same base was used in the first successful preparation of an α-lactam through cyclization of an α-chloro amide [H. E. Baumgarten, J. J. Fuerholzer, R. D. Clark, and R. D. Thompson, *J. Am. Chem. Soc.*, **85**, 3303 (1963)]. Here, however, the choice of base was less critical and other bases could have been used (with the appropriate laboratory technique). Most other workers have elected to follow our lead in the choice of base. However, we have experimented with other bases. In fact, one can use (with care) powdered KOH (in THF) to prepare certain α-lactams by cyclization of α-halo amides, but this is *not* recommended. Various Grignard and organolithium reagents were among the bases studied for such cyclizations, and we were able to observe (using ir techniques) but not to prepare α-lactams using these bases. Thus, in two experiments with **2c** (X = Br) and the methyl chloride Grignard reagent (in dilute solution) we did observe the appropriate ^1H NMR peaks for **1c** in both $CDCl_3$ and CCl_4. The amount of this product (if it were **1c**) was such (2.5–5%) as to preclude the use of this base for preparative purposes; however, our observation does suggest that, in the devising of mechanistic pathways for the reactions of α-halo amides with bases, one should consider α-lactam-like intermediates. One example where such an intermediate is a reasonable alternative may be found in ref 14f.

(18) A referee has suggested that the results with the methyl halide Grignard reagents which show yields of **4cw** in the order I < Br < Cl (and the high yield of **4cw** with dimethylmagnesium) may be indicative of a single electron transfer mechanism. He suggests further that the effect of ferric chloride may also indicate a SET mechanism and wonders what the reaction with the *tert*-butyl chloride Grignard reaction might reveal. These reasonable suggestions are not new to us; however, we believe that any detailed mechanisms for these reactions will require evidence well beyond what is available to us since small changes in structure seem to have a substantial effect on heterolytic vs. SET mechanisms in the addition of organometallic reagents to the carbonyl group [cf. E. C. Ashby, J. Laemmle, and H. M. Neumann, *Acc. Chem. Res.*, **7**, 272 (1974); T. Holm and I. Crossland, *Acta Chem. Scand.*, **25**, 59 (1971)]. Furthermore, some metal-catalyzed Kharasch-type couplings go by SET mechanisms; others do not.[14] In 1967 we carried out a single experiment in which **1a** was treated with 2 equiv of the *tert*-butyl chloride Grignard reagent. The isolated and purified product in 72% yield was **2c** (X = Cl). Recent experiments on 1-*tert*-butyl-2-phenylaziridinone with this reagent have given similar results, a high yield of the α-chloro amide plus a complex mixture of other products that are still under investigation. In experiments in progress both **1a** and **2a** have reacted with the dimethyllithium cuprate to give high yields (73–83%) of **9cw** together with small amounts of **8c**, but no **4cw**. This reaction is generally regarded as not proceeding by an SET mechanism [cf. H. O. House, *Acc. Chem. Res.*, **9**, 59 (1976)]. On the other hand, some α-lactams *do* appear to react with organometallic reagents preferentially by a SET mechanism, especially 1-*tert*-butyl-3,3-diphenylaziridinone.[9]

(19) See paragraph at end of paper regarding supplementary material.

(20) The first number in parentheses following a given bond length or angle is the root mean square estimated standard deviation of an individual datum. The second and third numbers, when included, are the average and maximum deviations from the average value, respectively.

(21) "International Tables for X-Ray Crystallography", Vol. III, "Physical and Chemical Tables", Kynoch Press, Birmingham, England, 1968, p 276.

(22) L. Pauling, "The Nature of the Chemical Bond", 3d ed, Cornell University Press, Ithaca, N.Y., 1960, p 260.

(23) E. C. Ashby and R. C. Arnot, *J. Organomet. Chem.*, **14**, 1 (1968).

(24) J. C. Sheehan and J. H. Beeson, *J. Am. Chem. Soc.*, **89**, 362 (1967).

(25) G. W. Tiers, *J. Phys. Chem.*, **62**, 1151 (1958).

(26) P. Laszlo, *Prog. Nucl. Magn. Reson. Spectrosc.*, **3**, 241 (1967).

(27) With this procedure the detection of as little as 1% of any product with the possible exception under certain conditions of **7c** and **3cw** was possible.

(28) "International Tables for X-Ray Crystallography", Vol. I, "Symmetry Groups", Kynoch Press, Birmingham, England, 1969, p 99.

(29) Reference 21, p 166.

(30) "International Tables for X-Ray Crystallography", Vol. II, "Mathematical Tables", Kynoch Press, Birmingham, England, 1967, p 302.

(31) D. T. Cromer and J. B. Mann, *Acta Crystallogr., Sect. A*, **24**, 321 (1968).

(32) W. H. Zachariasen, *Acta Crystallogr.*, **23**, 558 (1967).

Reactions of Amines. 20. Syntheses of Racemic and Optically Active Alkylhydrazines and *N*-Acyl-*N*-alkyl- and *N*-Acyl-*N*-arylhydrazines[1,2]

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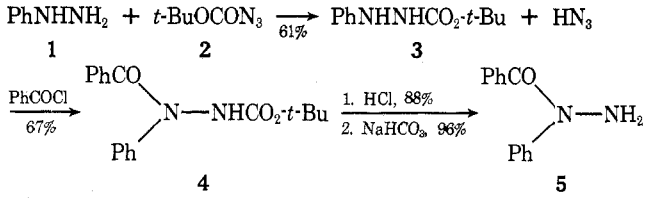
N-Acyl-*N*-alkyl- (**11**) and *N*-acyl-*N*-arylhydrazines (**5**) may be prepared by acylation of *N*-alkyl- (**9**) and *N*-aryl-*N'*-carbo-*tert*-butoxyhydrazines (**3**) followed by cleavage of the *N'*-carbo-*tert*-butoxy group. The intermediate **3** may be prepared by treatment of arylhydrazines with *tert*-butyl azidoformate (**2**). The intermediates **9** may be prepared by reduction of the corresponding ketone carbo-*tert*-butoxyhydrazones (**8**) or by the rearrangement [presumably via the diaziridinone (**17**)] of alkylureas (**15**). Cleavage of **9** prepared by the latter route has been used for the stereospecific synthesis of (*R*)-1-phenylethylhydrazine (**19a**) from (*R*)-1-phenylethylamine (**13a**) (via the urea **15a**).

Recently Moss and Powell[3] reported a new synthesis of hydrazines from alkyl diazotates that is sufficiently stereoselective to convert 1-phenylethylamine (**13a**) into 1-phenylethylhydrazine (**19a**) in 40% yield (as the oxalate) with a reported 54% net inversion of configuration. Like Moss and his coworkers, we have had a need for a simple, useful synthesis of optically active hydrazines but have found that most of the previously reported procedures[4,5] are deficient for our purpose in one respect or another. In addition we have required monosubstituted hydrazines with a *tert*-alkyl substituent and monosubstituted hydrazines acylated on the nonterminal nitrogen (i.e., *N*-aminoamides). This communication describes the procedures we are currently using for the synthesis of these several types of hydrazine derivatives. For this purpose the preparation of *N*-benzoyl-*N*-phenylhydrazine (**5**), several *N*-acyl-*N*-alkylhydrazines (**11**), racemic and optically active 1-phenylethylhydrazine (**19a**), *tert*-butylhydrazine (**22**), and related substances will be described.

Several early syntheses of **5** appear in the literature,[6,7] but none of these is convenient or efficient. Therefore, we have used the sequence shown in Chart I, which appears to be a

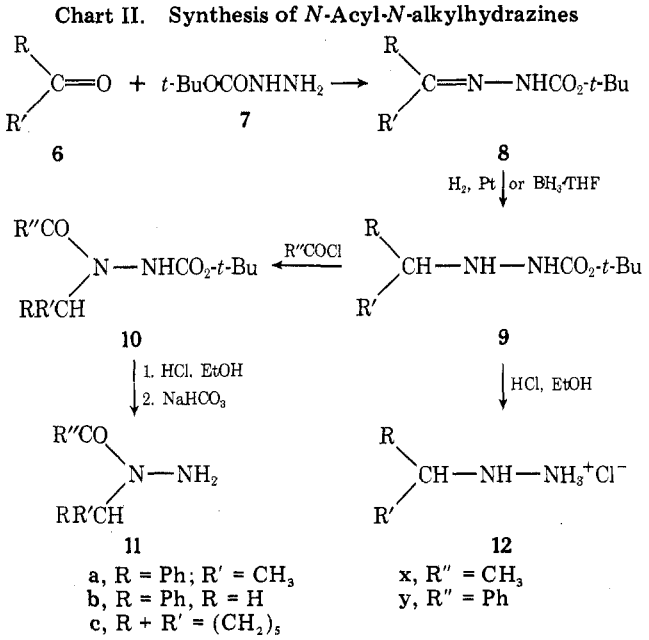
Chart I. Synthesis of *N*-Benzoyl-*N*-phenylhydrazine



potentially general synthesis for *N*-aminoanilides from the readily available arylhydrazines (**1**). The superiority of this synthesis over those used previously results from the use of the easily introduced [via *tert*-butyl azidoformate (**2**)] and easily removed (via mild acidic cleavage) *N*-carbo-*tert*-butoxy blocking group.[8] The overall yield of **5** from phenylhydrazine (**1**) was 35%. The identities of the products **3** and **5** were readily established by the characteristic differences in the ir and ^{1}H NMR spectra of *N*-acyl-*N*-arylhydrazines and *N'*-acyl-*N*-arylhydrazines[9] and confirmed for **5** by comparison with authentic samples made by an established procedure.[6] This identification shows that **1** is preferentially acylated on the terminal nitrogen with **2**.

Although the foregoing procedure should be useful for many arylhydrazines, it might be expected to be less effective with alkylhydrazines, which might react with **2** at either N atom. Therefore, the procedure in Chart II was developed for the

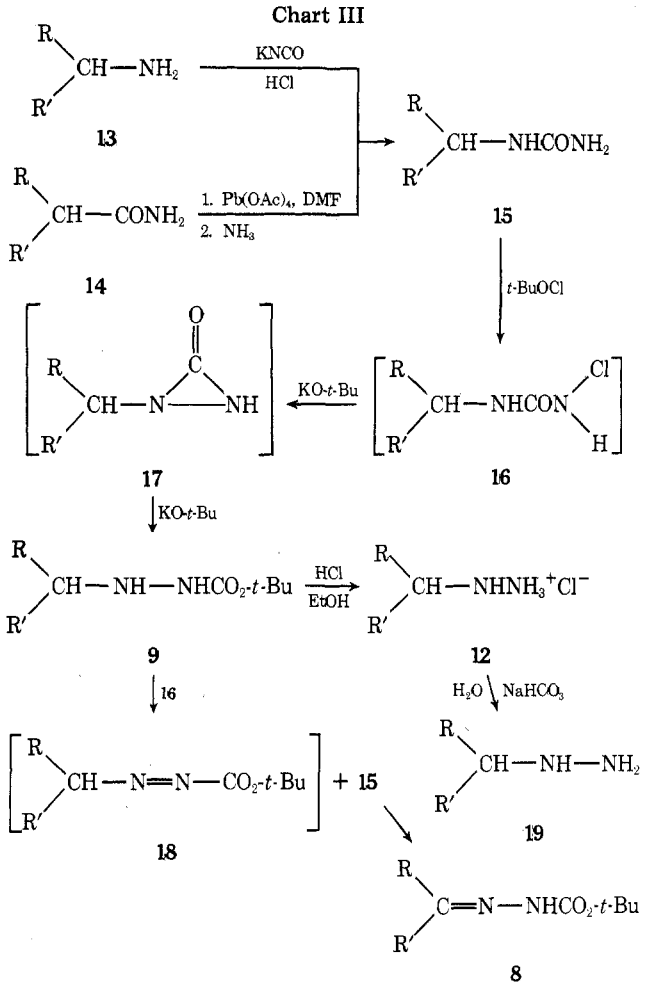
Chart II. Synthesis of *N*-Acyl-*N*-alkylhydrazines



synthesis of **11**. This synthesis could be modified (by elimination of the second acylation step) to afford a convenient variation on the previously reported[10,11] synthesis of alkylhydrazines [as the hydrochloride (**12**)] which used ethyl carbazate rather than *tert*-butyl carbazate (**2**).[12] The results of a number of preparations of **8** and **9** are summarized in Table I. Using the five-step process of Chart II hydrazides **IIax, IIay,** and **IIcy** were prepared in 43, 38, and 39% overall yields, respectively, from the corresponding ketones.

Although the procedure in Chart II is quite general, it cannot be used for optically active hydrazines (because the reductions of **8** to **9** shown are not stereoselective) nor for *tert*-alkylhydrazines. Attempts to bring about the stereoselective reduction of the carbo-*tert*-butoxyhydrazones of 2-methylcyclohexanone with potassium tri-*sec*-butylborane hydride[13] were unsuccessful. Attempts to develop a synthesis of *tert*-alkylhydrazines from **8** were thwarted when the addition of the methyl bromide Grignard reagent or methyllithium across the azomethine bond of **8b** gave at most 1–2% of **9a**. Rather than attempt to circumvent these experimental difficulties, we developed the route to **9** shown in Chart III.

Chart III

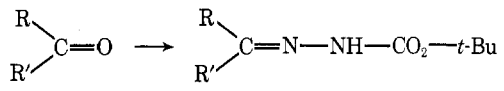


a, R = Ph; R' = CH_3
b, R = Ph; R' = H

This synthesis begins with an *N*-alkylurea (**15**), readily obtained from an amine (**13**) (racemic mixture or a single enantiomer) or a carboxamide[1] (**14**) (racemic mixture or single enantiomer) by the routes shown. Our expectation was that **15** would be converted by procedures well established in α-lactam[14] and diaziridinone[15] chemistry to, successively, the *N*-chloro urea (**16**), the unstable diaziridinone **17**, and finally the ring cleavage product, the *N'*-carbo-*tert*-butoxyhydrazine (**9**).

A similar procedure using sodium hypochlorite and aqueous base and leading directly to the hydrazine (or hydrazine derivative) was first reported by Schestakov[16] and apparently rediscovered recently.[17–19] The Schestakov procedure is described[16–18] as proceeding by halogenation on the terminal nitrogen atom followed by the Hofmann rearrangement (although this mechanistic route has been questioned[20]). Chlorination on the terminal nitrogen is to be expected *in alkaline media* where the reaction may involve displacement on the chlorine atom of the hypochlorite by amide anion. However, in neutral media N-chlorination by *tert*-butyl hypochlorite may involve a four- or six-center transition state[21] (steric factors permitting) and attack at the more basic (internal) nitrogen atom. We have attempted to determine the site of N-chlorination in **15b** and in **20** by comparison of the ^{1}H NMR spectra of the ureas with those of the crude *N*-chloro ureas.

Table I. Carbo-*tert*-butoxyhydrazones[a]



6 8

Registry no.	6	Yield, %	Mp, °C	Ir (CH_2Cl_2), cm^{-1} ν(N–H)	Ir (CH_2Cl_2), cm^{-1} ν(C=O)	^1H NMR ($CDCl_3$), δ[b]	Registry no. (8)
98-86-2	Acetophenone	84–94	169–170	3330	1740	2.17 (s 3)	56572-27-1
93-55-0	Propiophenone	72	169–171	3375	1750	2.65 (q 2)	60295-07-0
119-61-9	Benzophenone	92	142–145	3330	1740		60295-08-1
122-00-9	*p*-Methylacetophenone	90	142–144	3355	1735	2.14 (s 3)	60295-09-2
121-97-1	*p*-Methoxypropiophenone	90	163–165	3350	1735	2.60 (q 2)	60295-10-5
108-94-1	Cyclohexanone	91	125–127	3225[d]	1695[d]	0.90–2.50[e,f]	60295-11-6
583-60-8	2-Methylcyclohexanone	96	103–105	3440[g]	1730[g]	1.2–2.5[e]	60295-12-7
78-59-1	Isophorone	97	129–131			2.23 (s 2), 6.0 (m 1)	60295-13-8
98-53-3	4-*tert*-Butylcyclohexanone	100	137–139	3370	1735	1.20–2.75[e]	60295-14-9
1192-62-7	2-Acetylfuran	90	148.5–149.5	3350	1740	2.17 (s 3)	60295-15-0

[a] Satisfactory analytical data (±0.4% for C, H, N) were obtained for all new compounds in the table. [b] For α-CH protons only. *t*-BuO protons appeared at δ 1.50–1.54 except where otherwise noted. Aryl protons appeared as two clusters of peaks, roughly similar to those found in the spectrum of the parent ketone, range δ 6.75–8.00. [c] J = 7.5 Hz. [d] In KBr. [e] All ring protons. [f] *t*-BuO protons appeared at δ 1.50. [g] In CCl_4.

In **15b** the $-CH_2NH-$ moiety appears as a doublet and triplet. The $-CH_2-$ doublet appears to be shifted downfield upon chlorination but the splitting is retained, suggesting chlorination on the terminal N atom. However, there are enough other changes in peak shape, position, and area to render any decision somewhat ambiguous; thus, it is possible that both *N*-chloro species are present (or are in a slow equilibrium).

It is known from earlier studies[15] on *N,N'*-di-*tert*-butylurea, which has a single *tert*-butyl peak at δ 1.27 (in CCl_4), that chlorination gives an unstable *N*-chloro compound with two *tert*-butyl peaks at δ 1.32 and 1.41 (CCl_4) (our data, which are in close agreement with that reported[15]), corresponding to the *t*-BuNH and *t*-BuNCl moieties, respectively. Chlorination of *tert*-butylurea (**20**) [δ 1.37 ($CDCl_3$)] under the same conditions[15] gives a moderately stable crude solid with its principal *tert*-butyl peak at δ 1.39 ($CDCl_3$) (the only other *tert*-butyl peaks being caused by small amounts of unreacted **20** and *tert*-butyl alcohol, both of which are found *upfield* of δ 1.39). The very small shift in the position of the *tert*-butyl ^1H NMR peak upon chlorination suggests that chlorination occurs largely (if not exclusively) on the terminal nitrogen atom, and not on the nitrogen atom bearing the *tert*-butyl group, possibly because of steric inhibition of the transition state for the latter.

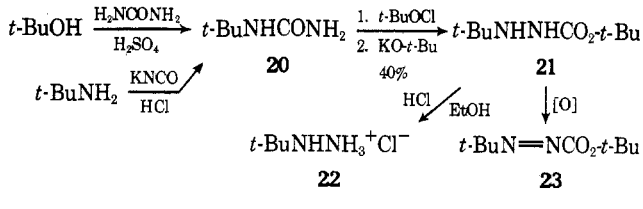
We also attempted to observe the proposed diaziridinone intermediate **17** using ir techniques similar to those we described earlier for the observation of α-lactams.[14] No ir peak in the 1850-cm^{-1} region was observed; therefore, the ring opening of **17** (if it is an intermediate) must be quite rapid. Thus, the question of the mechanism of this rearrangement remains unresolved. Although we prefer the general route shown, it is possible that a Hofmann rearrangement may be involved.

The new sequence, whether from **13, 14,** or **15** to **9,** is short and simple experimentally. Unfortunately, this synthetic sequence is not free from complication. Thus, with **13a** it was necessary to use a large excess (5–10 mol) of potassium *tert*-butoxide and to add **16a** *to the base* in the steps **16a** → **17a** → **9a.** When slightly more than the theoretical amount of base was used, the product was a mixture of **8a** and **9a** in ratios varying from 1:3 to 1:1 depending on other reaction variables. Apparently, the reaction of **16a** with the base is sufficiently slow that the product **9a** may be oxidized by the as yet uncyclized **16a** unless a large excess of base is used to accelerate the removal of **16a.** Presumably **9a** is oxidized to the corresponding azo compound, which then rearranges to **8a.** Of course any **8a** present can be readily hydrogenated back to **9a** (Chart II). This additional step would increase the overall yield of **9a** but would reduce the optical purity of the **9a.** If optical purity is not important, this may be the preferred procedure in some instances. For **13a, 8a** and **9a** could be separated.

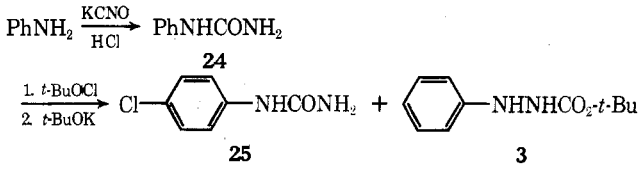
Cleavage of **9a** with hydrogen chloride went fairly easily in ethanol, and subsequent neutralization of the resultant hydrazinium salt (**12a**) gave the free hydrazine **19a.** In our hands the overall yield of **19a** from (*R*)-(+)-**13a** was 56%. Since our observed optical rotation for **19a** was slightly larger than the previously reported value for "pure" **19a,** presumably **19a** was obtained with essentially complete retention of configuration.[22,23]

Application of this synthetic route to benzylurea (**13b**) (using a large excess of base) gave an 82% yield of *N*-benzyl-*N'*-carbo-*tert*-butoxyhydrazine (**9b**) plus a trace of benzaldehyde carbo-*tert*-butoxyhydrazone (**8b**).

The route shown in Chart III could also be used for the synthesis of *tert*-butyl- and phenylhydrazine derivatives; however, the yields were substantially lower. In the synthesis of *tert*-butylhydrazine (**22**) it was again difficult to avoid the formation of the oxidation product **23;** furthermore, even



when a large excess of base was employed the yield of the intermediate hydrazide **21** was only 40%. However, there was also a 52% recovery of **20.** In the synthesis of *N*-phenyl-*N'*-carbo-*tert*-butoxyhydrazine (**3**) the intermediate *N*-chloro urea apparently underwent preferential rearrangement to *p*-chlorophenylurea (**25**) or was directly halogenated by the



tert-butyl hypochlorite, even under the usually favorable conditions of Chalsty and Israelstram.[24] The yield of **3** was 31% and that of **25** was 39% when the latter conditions were employed.

Experimental Section

Dichloromethane was distilled from phosphorus pentoxide under nitrogen. *tert*-Butyl alcohol was refluxed over calcium hydride for 24 h and distilled under nitrogen. Anhydrous ethanol was further dried by distillation with magnesium turnings. Benzene was dried by azeotropic distillation. *tert*-Butyl carbazate, *tert*-butyl azidoformate, and diborane–tetrahydrofuran complex were purchased from the Aldrich Chemical Co. Melting points were obtained with a Mel-Temp capillary melting point apparatus and are uncorrected. Infrared spectra were determined with Perkin-Elmer Models 137, 237, or 621 spectrometers. ^{1}H NMR spectra were determined at 60 MHz with a Varian A-60 or A-60D spectrometer. Chemical shifts are given in parts per million downfield from internal Me_4Si except for those determined in D_2O, which are based on the internal DOH peak (4.61 ppm). Mass spectra were taken on a Hitachi Perkin-Elmer RMU-6D mass spectrometer operated at 70 eV. Optical rotations were determined with a Perkin-Elmer Model 141 polarimeter using a 1-dm cell (critical values were measured on two different instruments of this type). Microanalyses were obtained from Micro-Tech Laboratories, Skokie, Ill.

***N*-Phenyl-*N'*-carbo-*tert*-butoxyhydrazine [*tert*-Butyl 2-Phenylcarbazate (3)].** A mixture of 11.44 g (0.0796 mol) of *tert*-butyl azidoformate, 8.6 g (0.0796 mol) of phenylhydrazine, 11.1 ml of triethylamine, and 20 ml of water was stirred for 40 h. The solid mass was broken up into small pieces. The yellow-orange solid was filtered, dried, and recrystallized from petroleum ether (bp 60–90 °C) to yield 10.0 g (61.0%) of **3** as white needles: mp 90–92 °C (lit.[25] 91–93 °C); ir (KBr) 3.05 (amide NH), 3.10 (amine NH), 5.80–5.95 (ester C=O), 8.3–8.7 μ (ester C–O–C); ^{1}H NMR ($CDCl_3$) δ 1.44 (9 H, s, *t*-Bu), 5.92 (1 H, s, NH), 6.62–7.37 (6 H, m, Ph + NH).

***N*-Benzoyl-*N*-phenyl-*N'*-carbo-*tert*-butoxyhydrazine (4).** To a solution of 5.0 g (0.024 mol) of **3** in 25 ml of dry pyridine, 3.38 g (0.024 mol) of benzoyl chloride was added dropwise over a period of 10 min. The reaction mixture was stirred for 12 h and was poured into ice and water. The cream colored precipitate was filtered, dried, and recrystallized from ethyl acetate–petroleum ether to yield 5.0 g (67.0%) of **4** as white crystals: mp 139–140 °C; ir (KBr) 3.05 (NH), 5.90 (urethane C=O), 6.05 (amide C=O), 8.50 μ (ester C–O–C); ^{1}H NMR ($CDCl_3$) δ 1.43 (9 H, s, *t*-Bu), 6.88 (1 H, s, NH), 7.05–7.82 (5 H, m, Ph).

Anal. Calcd for $C_{18}H_{20}N_2O_3$: C, 69.21; H, 6.45; N, 8.97. Found: C, 69.36; H, 6.48; N, 9.00.

***N*-Benzoyl-*N*-phenylhydrazine (5).** A solution of 4.9 g (0.0158 mol) of **4** in 50 ml of absolute ethanol was treated with anhydrous hydrogen chloride for 30 min. The white solid was filtered, washed with ether, and dried to yield 3.4 g (88.0%) of crude **5** hydrochloride: mp 196–198 °C; ir (KBr) 3.5–4.0 (+NH_3), 6.05 μ (C=O). To a solution of 4.9 g (0.0158 mol) of crude **5** hydrochloride in 25 ml of water a saturated solution of sodium bicarbonate was added until the mixture was basic to litmus. The aqueous solution was extracted with three 25-ml portions of chloroform. The dried extracts ($MgSO_4$) were treated with charcoal and evaporated to yield a light yellow oil. The oil was dissolved in a minimum amount of ethyl acetate and petroleum ether added until the solution became turbid. White crystals were obtained which were recrystallized in the same manner to yield 1.97 g (96.0%) of **5**: mp 63–65 °C (lit.[6] 67–69 °C); ir (KBr) 3.05–3.15 (NH_2), 6.10 μ (amide C=O); ^{1}H NMR ($CDCl_3$) δ 5.03 (2 H, s, NH_2), 7.00–7.50 (10 H, m, Ph + Ph).

Aldehyde and Ketone *tert*-Butoxycarbohydrazones (8). General Procedure. Equimolar amounts of *tert*-butyl carbazate or ethyl carbazate and the corresponding aldehyde or ketone (0.1–0.2 mol) were dissolved in an appropriate amount of absolute ethanol (30–75 ml), and the reaction mixture was stirred at room temperature until a copious precipitate had formed. A few drops of glacial acetic acid were added if the reaction mixture had been stirred for more than 24 h without formation of a precipitate. After filtration of the precipitate usually further precipitate could be obtained by adding small amounts of water to the filtrate. Generally, the combined precipitates were recrystallized by dissolving them in a sufficient amount of hot 95% ethanol and adding water dropwise to the cloud point, then setting the solution aside until recrystallization was completed (2–3 h).

For bulky ketones, such as benzophenone and 2-acetylfluorene, 0.5–1.0 ml of glacial acid was added at the beginning to the stirred mixture and the latter was heated under reflux for several hours. Benzophenone, 4-methoxypropiophenone, and 2-acetylfluorene *tert*-butoxycarbohydrazones were recrystallized from a mixture of 95% ethanol and 1,4-dioxane.

Selected results obtained using this procedure are given in Table I.[26]

N-Substituted *N'*-Carbo-*tert*-butoxyhydrazines (9). General Procedure. A. To a solution of 0.05 mol of **8** in 50–60 ml of 95% ethanol was added 0.3–0.4 g of 10% palladium on carbon.[27] The solution was mixed well and hydrogenated in the Paar shaker hydrogenator (starting pressure 45–50 psi). Generally, it took 2–3 h to complete the hydrogenation of the carbon–nitrogen double bond. Bulky *tert*-butoxycarbohydrazones required a longer reaction time. The reaction mixture was filtered through Celite, the filtrate was evaporated, and the residual solid was recrystallized from ethanol.

B. A dried three-necked round-bottomed flask was equipped with a pressure-equalized funnel, a nitrogen inlet and outlet device, a mechanical stirrer, and a condenser fitted with a calcium chloride tube. A solution of **8** in 60–80 ml of dry tetrahydrofuran was stirred and cooled (ice–salt bath) under a blanket of nitrogen, and twice the molar amount of diborane–tetrahydrofuran complex was transferred with an Aldrich Flex-needle under nitrogen pressure through a rubber septum to the sealed, pressure-equalized funnel. The diborane–tetrahydrofuran complex was then added dropwise through the funnel to the vigorously stirred reaction mixture. The reaction mixture was allowed to stand in the ice–salt bath for 1 h and then was stirred overnight at room temperature. The excess diborane was carefully destroyed by addition of 60 ml of a solution of THF and water (2:1). The resulting mixture was neutralized with dilute K_2CO_3 and extracted with three 40-ml portions of ether. The organic layer was dried ($MgSO_4$) and the solvent was evaporated under water aspirator pressure. The resulting oily material was dissolved in petroleum ether and passed through a silica gel column to remove dissolved inorganic material. The light yellow oily solution either yielded a precipitate on standing or gave an oily product on evaporation. Solid precipitates were recrystallized by dissolving them in a limited amount of 95% ethanol and adding water dropwise to the cloud point.

Selected results using these procedures are given in Table II.[26] All of the examples of **9** shown were prepared by procedure A. Three examples were also prepared by procedure B to compare the two procedures. The yield of **9a** from procedure B was 85%. The ir and ^{1}H NMR spectra of this product were identical with those for the product prepared by procedure A and the mixture melting point was not depressed. The other two compounds prepared by both procedures were oils but gave appropriate ir and ^{1}H NMR spectra.

***N*-Acetyl-*N*-(1-phenylethyl)-*N'*-carbo-*tert*-butoxyhydrazine (10ax).** To a solution of 12.0 g (0.05 mol) of **9a** in 75 ml of dry pyridine 5.1 g (0.05 mol) of acetic anhydride was added; the mixture was heated under reflux for 4 h and poured into ice water. The resulting yellow oil was extracted with three 50-ml portions of ether. The dried extracts ($MgSO_4$) were evaporated to a viscous oil. All attempts to crystallize the oil using chloroform–petroleum ether, ethyl acetate–petroleum ether, and ether–petroleum ether solvents were unsuccessful. The oil appeared to be hygroscopic. The yield of crude **10ax** was 10.1 g (72.5%): ir (neat) 3.10 (NH), 5.80 (C=O), 6.05 μ (C=O); ^{1}H NMR ($CDCl_3$) δ 1.18 (3 H, d, J = 7 Hz, CH_3), 1.48 (9 H, s, *t*-Bu), 2.06 (3 H, s, CH_3), 5.93 (1 H, q, J = 7 Hz, CH), 6.88–7.13 (1 H, s, NH), 7.33 (5 H, m, Ph).

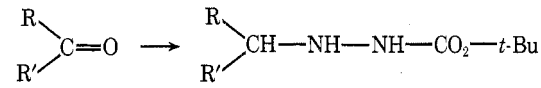
***N*-Acetyl-*N*-(1-phenylethyl)hydrazine (11ax).** A solution of 10.0 g (0.036 mol) of crude **10ax** in 50 ml of absolute ethanol was treated with anhydrous hydrogen chloride for 0.5 h. The ethanol was removed with a rotary evaporator leaving a thick yellow oil. The oil was dissolved in methanol, and ethyl ether was added until the solution became turbid. The mixture was allowed to crystallize to give 5.4 g (76.5%) of crude hydrochloride of **11ax**: mp 125–127 °C; ir (KBr) 3.4–3.8 (+NH_3), 6.05 μ (C=O).

A solution of 5.4 g (0.025 mol) of the crude hydrochloride in 25 ml of water was treated with a saturated solution of sodium bicarbonate until the solution was basic to litmus. The aqueous solution was extracted with three 25-ml portions of chloroform. The dried extracts ($MgSO_4$) were treated with charcoal and evaporated to dryness. The white solid remaining was recrystallized from chloroform–petroleum ether to give 3.9 g (87%) of **11ax**: mp 53–54 °C; ir (KBr) 3.05–3.10 (NH_2), 6.20 μ (C=O); ^{1}H NMR ($CDCl_3$) δ 1.48 (3 H, d, J = 7 Hz, CH_3), 2.19 (3 H, s, CH_3) 3.55 (3 H, s, NH_2), 6.11 (1 H, q, J = 7 Hz, CH), 7.32 (5 H, m, Ph).

Anal. Calcd for $C_{10}H_{14}N_2O$: C, 67.38; H, 7.92; N, 15.72. Found: C, 67.25; H, 7.93; N, 15.95.

***N*-Benzoyl-*N*-(1-phenylethyl)-*N'*-carbo-*tert*-butoxyhydrazine (10ay).** To a solution of 5.0 g (0.0212 mol) of **9a** in 50 ml of dry

Table II. Carbo-*tert*-butoxyhydrazines[a,b]



6 9

6	Yield, %	Mp, °C	Ir (CCl_4) cm^{-1} ν(NH)	Ir (CCl_4) cm^{-1} ν(C=O)	^1H NMR ($CDCl_3$), δ[c]	Registry no. (9)
Acetophenone	94[d,e]	72–73	3320	1710	4.17 (q 1)[f]	60295-16-1
Propiophenone	75	64–66	3330	1720	3.85 (m 1)	60295-17-2
Benzophenone	93	97–99	3440	1750, 1720	5.30 (s 1)	60295-18-3
p-Methylacetophenone	99	77–78.5	3435	1720	4.16 (q 1)[f]	60295-19-4
p-Methoxypropiophenone	99	60–62	3440	1720	3.5–3.95 (m 1)	60295-20-7
Cyclohexanone	82[g]	76–78	3225[h]	1695[h]	0.90–3.0[i]	60295-21-8
2-Methylcyclohexanone	85	Oil	3380	1710	1.05–3.00[i]	60295-40-1
Isophorone	97	151.5–153	3220	1750, 1700	1.60–2.65[i–k]	60295-41-2
4-*tert*-Butylcyclohexanone	96	Oil	3380	1700	1.0–2.0[i]	60295-42-3

[a] Satisfactory analytical data (± 0.4% for C, H, N) were obtained for all new compounds in the table. [b] Made by hydrogenation using Pd/C unless otherwise specified. [c] For CHN protons only. *t*-BuO protons appeared at δ 1.42–1.45 except where otherwise noted. Aryl protons appeared as sharp to broad singlets except for **9** from *p*-methoxyacetophenone which appeared in a distorted AB-like AA'BB' pattern, range 7.2–7.7. Alkyl protons appeared in their normal ranges. [d] Using BF_3·THF complex for reduction, yield was 85%. [e] Using 5% Pt/C (1.0 g/10 g of hydrazone) 73% of product was obtained after recrystallization from ethyl acetate–petroleum ether. [f] J = 6.5 Hz. [g] Obtained with 5% Pt/C (1.0 g/10 g of hydrazone). [h] In KBr. [i] All ring protons. [j] *t*-BuO protons at δ 1.50. [k] Ring double bond also reduced.

pyridine 3.0 g (0.0212 mol) of benzoyl chloride was added dropwise. The reaction mixture was stirred for 15 h and poured into ice cold 4 N hydrochloric acid. The aqueous solution was extracted with three 50-ml portions of chloroform. The dried extracts ($MgSO_4$) were treated with charcoal and evaporated to dryness. The white solid was recrystallized from chloroform–petroleum ether to give 5.3 g (76%) of **10ay**: mp 115–117 °C; ir (KBr) 3.10–3.15 (NH), 5.90 μ (C=O); ^1H NMR ($CDCl_3$) δ 1.18 (9 H, s, *t*-Bu), 1.58 (3 H, d, J = 7 Hz, CH_3), 5.83 (1 H, q, J = 7 Hz, CH), 6.77 (1 H, broad s, NH), 7.03–7.67 (6 H, m, Ph + NH).

Anal. Calcd for $C_{20}H_{24}N_2O_3$: C, 70.56; H, 7.11; N, 8.23. Found: C, 70.50; H, 7.13; N, 8.24.

***N*-Benzoyl-*N*-(1-phenylethyl)hydrazine (11ay).** A solution of 5.3 g (0.0156 mol) of **10ay** in 50 ml of absolute ethanol was treated with anhydrous hydrogen chloride for 0.5 h. The ethanol was removed by evaporation, leaving a thick yellow syrup (the hydrochloride salt was hygroscopic). The syrup was treated with 30 ml of a saturated solution of sodium bicarbonate until basic to litmus and the solution was extracted with three 50-ml portions of chloroform. The dried extracts ($MgSO_4$) were treated with charcoal and evaporated to dryness. The light yellow oil was dissolved in chloroform and petroleum ether added until the solution turned cloudy. White needles of **11ay** were obtained: yield 2.1 g (56%); mp 56–67 °C; ir (KBr) 3:05–3.10 (NH_2), 6.20 μ (C=O); ^1H NMR ($CDCl_3$) δ 1.57 (3 H, d, J = 6.5 Hz, CH_3), 3.91 (2 H, broad s, NH_2), 5.33 (1 H, q, J = 6.5 Hz, CH), 7.30 (5 H, s, PhCH), 7.45 (5 H, s, PhCO).

Anal. Calcd for $C_{15}H_{16}N_2O$: C, 74.97; H, 6.71; N, 11.66. Found: C, 74.75; H, 6.80; N, 11.75.

***N*-Benzoyl-*N*-cyclohexylhydrazine (11cy).** To a solution of 10.0 g (0.0467 mol) of **9c** in 30 ml of methylene chloride was added 5.3 ml (0.0467 mol) of benzoyl chloride and the reaction mixture allowed to stir for 5 h. The methylene chloride was removed with a rotary evaporator leaving a white solid which liquefied upon filtration. The hygroscopic substance was redissolved in ethanol and the solution was treated with anhydrous hydrogen chloride for 30 min. The ethanol was evaporated leaving a white solid which was recrystallized from ethanol–water to give 7.2 g (61%) of the crude hydrochloride of **11cy**; mp 176–180 °C; ir (KBr) 3.5–4.0 (+NH_3), 6.1 μ (C=O); ^1H NMR ($CDCl_3$) δ 0.68–2.65 (10 H, broad m, C_6H_{10}), 3.45–4.12 (1 H, broad s, CH), 7.60 (5 H, s, Ph), 9.13 (3 H, broad s, +NH_3).

To a solution of 10.0 g (0.0392 mol) of the crude hydrochloride in 50 ml of water was added a sufficient amount of saturated sodium bicarbonate to make the solution basic to litmus. The mixture was extracted with three 50-ml portions of chloroform, and the extracts were dried ($MgSO_4$) and evaporated to dryness, leaving a white solid. Recrystallization from water–ethanol gave **11cy** as white platelets, yield 7.3 g (86%): mp 118–119 °C; ir (KBr) 3.0–3.1 (NH_2), 6.1 (amide C=O), 6.3 (NH in plane bend), 13.3 (NH_2 out of plane bend), in $CHCl_3$ 2.9–3.0 (NH_2), 6.1 (C=O), 6.3 μ (NH_2 deformation); ^1H NMR ($CDCl_3$) δ 0.92–2.08 (10 H, broad m, C_6H_{10}), 3.51–3.91 (1 H, broad m, CH), 4.00–4.33 (2 H, broad s, NH_2), 7.55 (5 H, s, Ph); mass spectrum (80 eV) *m/e* rel intensity and pertinent metastables) 218 (27.6), 202 (1), 136 (24.8), 105 (100), 77 (39), 84.8 (218 → 136), 50.6 (218 → 105), 81.1 (136 → 105), 56.5 (105 → 77).

Anal. Calcd for $C_{13}H_{18}N_2O$: C, 71.52; H, 8.31; N, 12.83. Found: C, 71.40; H, 8.36; N, 12.72.

N-Substituted Ureas. General Procedure. A solution of 0.10 mol of the amine in a mixture of 8.3 ml of concentrated hydrochloric acid and 100 ml of water was added to a solution of 8.1 g (0.10 mol) of potassium cyanate in 100 ml of water. The mixture was stirred at room temperature for 6 h. The white precipitate was collected by filtration and washed with water. For *N*-*tert*-butylurea (**20**) it was necessary to remove the water (rotary evaporator) because of the solubility of the product in water. The ureas were recrystallized from ethanol.

The yield of **1-phenylethylurea (15a)** was 83%: mp 110–112 °C (lit.[28] mp 112–113.5 °C); ^1H NMR (Me_2SO-d_6) δ 1.31 (3 H, d, J = 6.5 Hz, CH_3), 4.73 (1 H, q, J = 6.5 Hz, CH), 5.46 (2 H, broad s, NH_2), 6.43 (1 H, d, J = 6.5 Hz, NH), 7.28 (5 H, s, Ph).

(*R*)-(+)-1-Phenylethylurea (15a) was prepared from (*R*)-(+)-1-phenylethylamine [^1H NMR (CCl_4) δ 1.29 (3 H, d, J = 6.5 Hz, CH_3), 1.47 (2 H, s, NH_2), 3.99 (1 H, q, J = 6.5 Hz, CH), 7.22 (5 H, s, Ph); $[\alpha]^{25}_{589}$ +36.47° (neat), $[\alpha]^{25}_{589}$ +38.28°,[27] $[\alpha]^{25}_{589}$ +28.32° (*c* 2.020, EtOH), 94.3% optically pure (lit.[29] $\alpha^{22}D$ −38.30° (neat, 1 dm); $[\alpha]^{25}D$ +40.6° (neat))]: yield 84%; mp 118–120 °C [lit.[30] mp for (*S*)-(−)-urea 123.5–124 °C]; ^1H NMR (Me_2SO-d_6) δ 1.30 (3 H, d, J = 6.5 Hz, CH_3), 4.73 (1 H, q, J = 6.5 Hz, CH), 5.48 (2 H, broad s, NH_2), 6.46 (1 H, d, J = 7 Hz, NH), 7.28 (5 H, s, Ph).

The yield of ***tert*-butylurea**[31] (**20**) was 50%: mp 182–184 °C (lit.[32] mp 183 °C); ^1H NMR (Me_2SO-d_6) δ 1.21 (9 H, s, *t*-Bu), 5.23 (2 H, broad s, $-NH_2$), 5.82 (1 H, broad s, –NH); ^1H NMR ($CDCl_3$) δ 1.37 (s, *t*-Bu).

The yield of **benzylurea (15b)** was 93%: mp 145–146 °C (lit.[33] mp 146.6 °C); ^1H NMR (Me_2SO-d_6) δ 4.20 (2 H, d, J = 6 Hz, CH_2), 5.70 (2 H, s, NH_2), 6.57 (1 H, broad t, J = 6 Hz, NH), 7.27 (5 H, s, Ph).

The yield of **phenylurea (24)** was 72%: mp 145–146 °C (lit.[33] mp 147–148 °C); ^1H NMR (Me_2SO-d_6) δ 5.90 (2 H, s, NH_2), 6.76–7.55 (5 H, m, Ph), 8.58 (1 H, s, NH).

Rearrangement of 1-Phenylethylurea (15a). To a stirred mixture of 1.64 g (0.010 mol) of **15a**, 20 ml of dry benzene, and 15 ml of dry *tert*-butyl alcohol kept at 0–5 °C (ice–salt bath) was added dropwise but rapidly 1.2 ml (1.09 g, 0.01 mol) of *tert*-butyl hypochlorite.[34] When the mixture became clear (1–2 min), the resultant solution (all of the urea had dissolved as it reacted) was added rapidly into a precooled (5 °C) solution of 5.6 g (0.05 mol) of potassium *tert*-butoxide in 30 ml of dry benzene and 30 ml of dry *tert*-butyl alcohol. The mixture was stirred for an additional 5–10 min and then poured with stirring into 300 ml of ice water. The aqueous layer was extracted with 1:1 methylene chloride–ether, and the combined organic layers were washed with water, dried ($MgSO_4$), and evaporated. The crude product (1.94 g, 82%) was a mixture of ***N*-(1-phenylethyl)-*N'*-carbo-*tert*-butoxyhydrazine (9a)** and a small amount of **8a**. The latter was relatively insoluble in *n*-pentane. Thus, recrystallization from *n*-pentane gave 1.78 g (75%) of **9a**: mp 72–73 °C; ^1H NMR δ ($CDCl_3$) 1.25 (3 H, d, J = 6.5 Hz, CH_3), 1.44 (9 H, s, *t*-Bu), 4.16 (1 H,

q, J = 6.5 Hz, CH), 4.00 (1 H, broad s, –NH), 6.16 (1 H, broad s, –NH), 7.32 (5 H, s, Ph). Alternatively, the crude product could be purified by chromatography on silica gel using 1:1 $CHCl_3$–*n*-pentane as eluent. Compound **9a** was eluted before **8a**.

Similar treatment of (*R*)-(+)-**15a**, $[\alpha]^{25}_{589}$ +45.11° (*c* 1.024, EtOH), gave 84% of (*R*)-(+)-**9a**: mp 70–74 °C; ^{1}H NMR δ ($CDCl_3$) 1.28 (3 H, d, J = 6.5 Hz, CH_3), 1.41 (9 H, s, *t*-Bu), 4.16 (1 H, q, J = 6.5 Hz, CH), 3.99 (H, broad s, –NH), 6.66 (H, broad s, –NH), 7.31 (5 H, s, Ph); $[\alpha]^{25}_{589}$ +97.44° (*c* 1.125, EtOH).

Rearrangement of *tert*-Butylurea (20). The procedure was essentially the same as that used for **15a** except that the unreacted **20** (52%) was recovered by evaporation of the aqueous layers. The yield of ***N*-*tert*-butyl-*N'*-carbo-*tert*-butoxyhydrazine (21)** was 40%: mp 66–68 °C; ^{1}H NMR ($CDCl_3$) δ 1.36 (9 H, s, *t*-Bu), 1.42 (9 H, s, *t*-Bu).

Anal. Calcd for $C_9H_{20}N_2O_2$: C, 57.42; H, 10.74; N, 14.87. Found: C, 57.15; H, 10.87; N, 14.92).

Chlorination of 20. To a solution of 0.387 g (0.0033 mol) of **20** in 12 ml of methanol, 0.36 g (0.4 ml, 0.0033 mol) of *tert*-butyl hypochlorite was added with stirring at 0 °C (ice–salt bath). After 3 min the methanol was removed under vacuum (<0.5 Torr) at −10 to 0 °C. The residue (a white solid) was dissolved in $CDCl_3$ and analyzed by ^{1}H NMR: δ ($CDCl_3$) 1.28 (s, *t*-BuOH), 1.37 (s, **20**), 1.39 (s, *t*-BuNHCONHCl). The first two peaks were quite small. Addition of a small drop of *t*-BuOCl caused the area of the peaks at δ 1.28 and 1.39 to increase and that at δ 1.37 to decrease. Treatment of the crude *N*-chloro compound with potassium *tert*-butoxide in benzene–*tert*-butyl alcohol gave essentially the same mixture (based on its ^{1}H NMR spectrum) of **20** and **21** as that described for the rearrangement of **20**.

Similar treatment of *N,N'*-di-*tert*-butylurea[15] [δ (CCl_4) 1.27 (s, *t*-Bu)] gave a crude product with ^{1}H NMR (CCl_4) δ 1.32 (*t*-BuNH), 1.41 (*t*-BuNCl) [lit.[15] ^{1}H NMR (CCl_4) δ 1.33, 1.43].

Rearrangement of Benzylurea (15b). The procedure was essentially the same as that used for 1-phenylethylurea. ***N*-Benzyl-*N'*-carbo-*tert*-butoxyhydrazine (9b)** was extracted into pentane and purified by distillation to yield 82% of product: bp 100–105 °C (0.1 Torr); ^{1}H NMR ($CDCl_3$) δ 1.44 (9 H, s, *t*-Bu), 3.92 (2 H, s, CH_2), 4.25 (1 H, broad, NH), 6.83 (1 H, broad, NH), 7.27 (5 H, s, Ph).

Anal. Calcd for $C_{12}H_{18}N_2O_2$: C, 64.84; H, 8.16; N, 12.60. Found: C, 64.72; H, 7.99; N, 12.40.

A trace of benzaldehyde carbo-*tert*-butoxyhydrazone (**8b**) was left as the pentane-insoluble residue: mp 187–189 °C (lit.[35] mp 190–191 °C); ^{1}H NMR ($CDCl_3$) δ 1.52 (9 H, s, *t*-Bu), 7.25–7.80 (5 H, m, Ph), 7.85 (1 H, s, NH), 8.30 (1 H, s, –CH=).

Rearrangement of Phenylurea (24). A. The procedure used for the rearrangement of **15b** was followed. The methylene chloride–ether extracts were washed with water, dried ($MgSO_4$), and evaporated. The crude product was extracted with petroleum ether to give a 15% yield of *N*-phenyl-*N'*-carbo-*tert*-butoxyhydrazine (**3**): mp 91–92 °C (lit.[36] 91–93 °C); ^{1}H NMR ($CDCl_3$) δ 1.43 (9 H, s, *t*-Bu), 5.82 (1 H, broad, NH), 6.57 (1 H, broad, NH), 6.67–7.40 (5 H, m, Ph). The petroleum ether insoluble residue was essentially pure *p*-chlorophenylurea (**25**), yield 50%: mp 204–206 °C (lit.[37] mp 206 °C); ^{1}H NMR (Me_2SO-d_6) δ 5.94 (2 H, s, NH_2), 7.35 (5 H, m, Ar), 8.70 (1 H, s, NH).

B. To a stirred mixture of 1.36 g (0.0100 mol) of phenylurea, 40 ml of dry *tert*-butyl alcohol, and 1.6 g of Borax was added dropwise at room temperature 1.2 ml (1.09 g, 0.0100 mol) of *tert*-butyl hypochlorite. The temperature of the mixture rose to 30 °C. When the temperature fell to ambient, the resultant solution was added rapidly to a precooled (5 °C) solution of 5.6 g (0.050 mol) of potassium *tert*-butoxide in 30 ml of dry benzene and 30 ml of dry *tert*-butyl alcohol. The mixture was stirred for an additional 5–10 min and then poured with stirring into 300 ml of ice and water. The aqueous layer was extracted with 1:1 methylene chloride–ether, and the combined organic layers were washed with water, dried ($MgSO_4$), and evaporated. The crude product (1.20 g, 58%) was extracted with petroleum ether to give 0.65 g (31%) of **3**. The residue gave 0.50 g (39%) of *p*-chlorophenylurea.

Cleavage of N-Substituted *N'*-Carbo-*tert*-butoxyhydrazines. General Procedure. In general the carbo-*tert*-butoxyhydrazines **9** were cleaved by passing anhydrous HCl through solutions of **9** in absolute ethanol (ca. 20–30 ml/0.1 mol) with stirring at the ice bath temperature until the reaction mixture became milky in appearance. Passage of the HCl was continued for ca. 1 h; then the mixture was stirred for 1–2 h under nitrogen. Anhydrous ether was added to the mixture (in some instances) and he mixture was stored in the freezer overnight. The product was collected by suction filtration (under nitrogen) and (if desired) recrystallized from a limited amount of methanol (adding anhydrous ether as necessary), again with storage of the recrystallization mixture in the freezer overnight. Suction filtration (under nitrogen) and washing with anhydrous ether gave the crude hydrazine hydrochloride (**12**), which was stored under nitrogen in a drybox. Elemental analysis of several such hydrochlorides showed them to be mixtures of the mono- with relatively small amounts of the dihydrochlorides. Further purification of **12** was not particularly effective, and, since for our purposes the mixtures sufficed, little effort was expended in this direction. The following specific examples demonstrate what can be done where a more nearly pure sample of the hydrazine (**19**) is required.

Hydrogen chloride was passed into a solution of 4.93 g (0.209 mol) of the (*R*)-(+)-**9a** described above in 50 ml of absolute ethanol with stirring (magnetic) and cooling (ice–salt bath). The reaction temperature was kept under 30 °C. After a white precipitate began to form (about 0.5–1 h) the passage of HCl was continued for 1 h. The mixture was diluted with dry ether and stored in the freezer overnight. The solid that formed was filtered under nitrogen and washed with dry ether, yielding 3.55 g (98.6%) of crude (*R*)-(+)-1-phenylethylhydrazine hydrochloride (**12a**): mp 179–180 °C; ^{1}H NMR (D_2O) δ 1.27 (3 H, d, J = 7.0 Hz, CH_3), 4.08 (1 H, q, J = 7.0 Hz, CH), 7.17 (5 H, s, Ph).

To a solution of 1.72 g (0.01 mol) of (*R*)-(+)-**12a** in 30 ml of water a 1 N solution of sodium bicarbonate in water was added slowly with stirring until the solution was basic to litmus. The mixture was extracted quickly with three 50-ml portions of chloroform, and the chloroform solutions were dried ($MgSO_4$) and evaporated under a stream of nitrogen. Distillation of the residue gave 1.2 g (89%) of **(*R*)-(+)-1-phenylethylhydrazine (19a)**: bp 74 °C (1 mm) [lit.[38] bp 75 °C (1.1 mm)]; ^{1}H NMR ($CDCl_3$) δ 1.26 (3 H, d, J = 6.5 Hz, CH_3), 3.06 (3 H, s, NH + NH_2), 3.68 (1 H, q, J = 6.5 Hz, CH), 7.30 (5 H, s, Ph); $[\alpha]^{25}_{589}$ +32.49° (*c* 1.010, benzene) [lit.[22,23] $[\alpha]^{25}$D −30.3° (*c* 0.784, benzene) for the *optically pure* (*S*)-(−) isomer].

Treatment of 0.648 g (0.00345 mol) of **21** in 30 ml of absolute ethanol with hydrogen chloride as described above gave 0.46 g (107%) of crude ***tert*-butylhydrazine hydrochloride (22).** The crude product was dissolved in hot 1:1 methanol–ethyl acetate, filtered, and diluted with ethyl acetate until the solvent composition was ca. 1:5. After storage in the freezer 0.409 g (95%) of product was obtained: mp 191–192 °C (lit.[39] mp 192–194 °C); ^{1}H NMR (D_2O) δ 1.27 (s, *t*-Bu).

Registry No.—**1**, 100-63-0; **2**, 1070-19-5; **3**, 42116-43-8; **4**, 60295-43-4; **5**, 579-45-3; **5** HCl, 13815-63-9; **8b**, 24469-50-9; (+)-**9a**, 60325-12-4; **9b**, 53370-84-6; **10ax**, 60295-44-5; **10ay**, 60295-45-6; **11ax**, 60295-46-7; **11ax** HCl, 60295-47-8; **11ay**, 60295-48-9; **11cy**, 60295-49-0; **11cy** HCl, 60295-50-3; (+)-**12a**, 60362-49-4; (±)-**13a**, 618-36-0; (+)-**13a**, 3886-69-9; **13b**, 100-46-9; (±)-**15a**, 60295-51-4; (+)-**15a**, 16849-91-5; **15b**, 538-32-9; (+)-**19a**, 60325-13-5; **20**, 1118-12-3; **20** *N*-chloro derivative, 25544-61-0; **21**, 60295-52-5; **22**, 7400-27-3; **24**, 64-10-8; **25**, 140-38-5; benzoyl chloride, 98-88-4; acetic anhydride, 108-24-7.

References and Notes

(1) Part 19: H. E. Baumgarten, D. G. McMahan, V. J. Elia, B. I. Gold, V. W. Day, and R. O. Day, *J. Org. Chem.*, preceding paper in this issue.
(2) This work was supported in part by Grant GP-28261 from the National Science Foundation and a traineeship to H.W.T. from the National Aeronautics and Space Administration.
(3) R. A. Moss and C. E. Powell, *J. Org. Chem.*, **40**, 1213 (1975).
(4) See ref 3–10 in ref 3.
(5) E. Müller in E. Müller, "Methoden der Organische Chemie" (Houben-Weyl), Vol. IX, Part 2, Georg Thieme Verlag, Stuttgart, 1967, pp 5–62.
(6) G. L. Lockemann, *Chem. Ber.*, **43**, 2223 (1910).
(7) E. G. Laws and N. N. Sidgwick, *J. Chem. Soc.*, 2085 (1911).
(8) L. A. Carpino, *Acc. Chem. Res.*, **6**, 191 (1973).
(9) H. E. Baumgarten, P. L. Creger, and R. L. Zey, *J. Am. Chem. Soc.*, **82**, 3977 (1960).
(10) M. C. Chaco, P. R. Stapp, J. A. Ross, and N. Rabjohn, *J. Org. Chem.*, **27**, 3371 (1962).
(11) M. C. Chaco and N. Rabjohn, *J. Org. Chem.*, **27**, 2765 (1962).
(12) In several earlier attempts we encountered some difficulty in selectively hydrolyzing the carboethoxy group in the carboethoxy analogue of **10**.
(13) H. C. Brown and S. Krishnamurthy, *J. Am. Chem. Soc.*, **94**, 7159 (1972).
(14) H. E. Baumgarten, *J. Am. Chem. Soc.*, **84**, 4975 (1962).
(15) F. D. Greene, J. C. Stowell, and W. R. Bergmark, *J. Org. Chem.*, **34**, 2254 (1969).
(16) P. Schestakov, *Z. Angew. Chem.*, **16**, 1061 (1903); cf. J. S. Chalsty and S. S. Israelstam, *J. S. Afr. Chem. Inst.*, **9**, 37 (1956), for other references.
(17) D. W. Lum and I. L. Mador, U.S. Patent 2 917 545; *Chem. Abstr.*, **54**, 6549e (1960); cf. ref 5, p 34.
(18) A. Stempel, J. Zelauskas, and J. A. Aeschlimann, *J. Org. Chem.*, **20**, 412 (1955).
(19) H. Gustafsson and U. Ragnarsson, *Acta Pharm. Suec.*, **11**, 493 (1974); H. Gustafson, *Acta Chem. Scand., Ser. B*, **29**, 93 (1975).
(20) P. A. S. Smith, "The Chemistry of Open-Chain Organic Nitrogen Com-

pounds", Vol. I., W. A. Benjamin, New York, N.Y., 1965, p 274.
(21) I. Weil and J. C. Morris, *J. Am. Chem. Soc.*, **71**, 1664 (1949).
(22) K. R. Kopecky and T. Gillan, *Can. J. Chem.*, **47**, 2371 (1969).
(23) Reaction of 95.6% optically pure (*S*)-(−)-1-phenylethylamine with hydroxylamine-*O*-sulfonic acid gave 8% of pure (*S*)-(−)-1-phenylethylhydrazine, $[\alpha]^{25}D$ −29.0° (*c* 0.784, benzene).[22] From these data Moss and Powell[3] have calculated the specific rotation of the *optically pure* hydrazine to be $[\alpha]^{25}D$ −30.3° (*c* 0.784, benzene) and have used the result to estimate not only the optical purity of their own hydrazine but also the stereoselectivity of their method of preparation. We believe that an accurate value for the specific rotation of (+)-**19a** cannot be based on the earlier data[22] because the optical purity of the (−)-**19a** would depend upon the efficacy of the separation of a small amount of (−)-**19a** from a large amount of unreacted **13a** by vacuum distillation through a 6-in. Vigreux column.
(24) J. S. Chalsty and S. S. Israelstam, *J. S. Afr. Chem. Inst.*, **9**, 33 (1956).
(25) L. A. Carpino, *J. Am. Chem. Soc.*, **79**, 4427 (1957).
(26) Other examples may be found in the Ph.D. Theses of H. W. Taylor (1971) and D. R. Hwang (1974), University of Nebraska–Lincoln.
(27) In a few experiments 5% Pt/C for 10 g of substrate was substituted for Pd/C. In these instances the Pt/C catalyst was wet with about 3 ml of water before being added to the hydrogenation vessel.
(28) P. Adams, U.S. Patent 3 161 676 [*Chem. Abstr.*, **62**, 9023*h* (1965)].
(29) Calculations based on density and rotation values cited by A. Ault, "Organic Syntheses", Collect. Vol. V, Wiley, New York, N.Y., 1973, p 932.
(30) A. P. Terent'ev, R. A. Gracheva, and V. T. Bezruchko, *J. Org. Chem. USSR (Engl. Transl.)*, **5**, 1048 (1969).
(31) Available commercially or by preparation from *tert*-butyl alcohol (which gives a better product than that from KNCO): L. I. Smith and O. H. Emerson, "Organic Syntheses", Collect Vol. III, Wiley, New York, N.Y., 1955, p 15.
(32) M. Brander, *Recl. Trav. Chim. Pays-Bas*, **37**, 67 (1917).
(33) T. L. Davis and K. C. Blanchard, *J. Am. Chem. Soc.*, **45**, 1816 (1923); "Organic Syntheses", Collect. Vol. I, Wiley, New York, N.Y., 1941, p 453.
(34) M. J. Mintz and C. Walling, "Organic Syntheses", Collect Vol. V, Wiley, New York, N.Y., 1973, p 184.
(35) R. Ohme, East German Patent 64 463 (1968); *Chem. Abstr.*, **71**, 49335t (1968).
(36) L. A. Carpino, *J. Am. Chem. Soc.*, **79**, 4427 (1957).
(37) B. Singh, H. Krall, and R. Sahasrabudhey, *J. Indian Chem. Soc.*, **23**, 373 (1946).
(38) C. G. Overberger and A. V. Di Giulio, *J. Am. Chem. Soc.*, **80**, 6562 (1958).
(39) O. Westphal, *Chem. Ber.*, **74B**, 759 (1941).

Reactions of *N*-Sulfinylarylamines with Carbonyl Compounds and a Nitrile in the Presence of Copper

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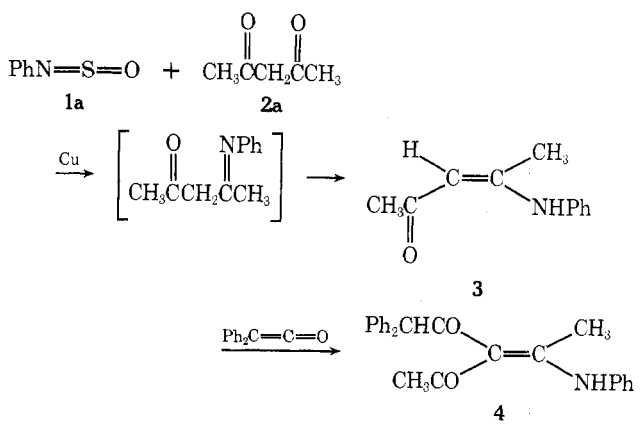
The copper-catalyzed reactions of *N*-sulfinylarylamines **1a,b** with activated carbonyl **2a–d,f** and nitrile compounds **12** were studied. Each carbonyl compound gave amino ketones **3, 5, 8, 9,** and **11** and sulfides **6** and **7.** Phenylacetonitrile (**12**) yielded *trans*-α,β-dicyanostilbene (**13**). The formation mechanism of these products was discussed.

Reactions of *N*-sulfinyl-*p*-toluenesulfonamides with various aldehydes and ketones can lead to *N*-sulfonylimines,[1,2] oxathioles,[3,4] and α-sulfonamido ketones.[5] In this paper we report on the reactions of the less reactive *N*-sulfinylanilines and the effect of copper[6] in these reactions.

A mixture of *N*-sulfinylaniline (**1a**), acetylacetone (**2a**), and copper shavings in mesitylene was refluxed for 6 h to give 4-anilino-3-penten-2-one (**3**)[10] in 46% yield; gas was evolved. Without copper, however, only starting **1a** and **2a** were recovered. Thus, copper catalyzes the formation of the enamino ketone **3** from **1a** and **2a.**

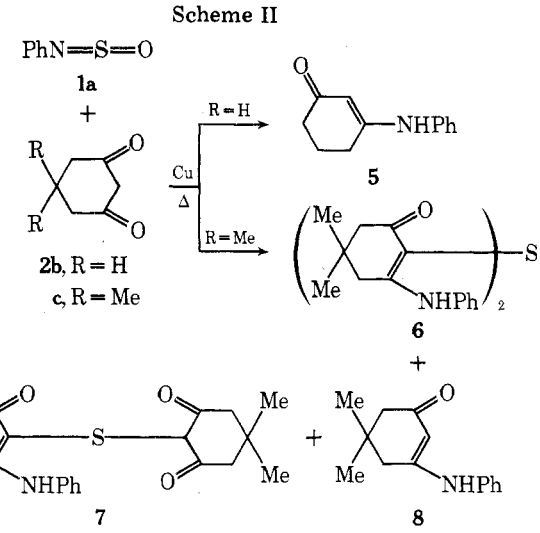
Scheme I



The reaction of **3** with diphenylketene gave **4,** analogous to the products from enamino ketones and isothiocyanates.[7]

The reaction between **1a** and 1,3-cyclohexanedione (**2b**) similarly took place to provide 3-anilino-2-cyclohexen-1-one (**5**) in quantitative yield.

Scheme II



In contrast to **2b,** use of 5,5-dimethyl-1,3-cyclohexanedione (**2c**) gave rise to the formation of unexpected sulfide **6** in 67% yield along with two minor products, the sulfide **7** (16%) and the anilino ketone **8** (12%).

In a separate reaction, treatment of **8** with sulfur under the same conditions gave the sulfide **6** in good yield. Similar treatment of an equimolar mixture of **8** and **2c** with sulfur afforded a mixture of **6** (40%) and the unsymmetrical sulfide **7** (43%). These results suggest that the sulfides, **6** and **7,** were formed in the reaction by oxidative coupling between **8** and either a second molecule of **8** or **2c** in the presence of elemental sulfur. The latter could be produced by reduction of sulfur dioxide or sulfur monoxide on copper in the reaction system.