Diaziridinones. III. Reactions with Hydrazines. Isomerization of Diaziridinones to Aziridinecarboxamides by Hydrazine Catalysis[1]

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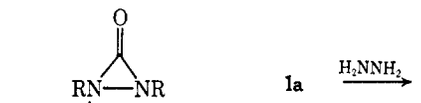
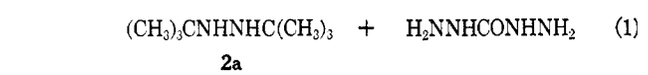
Diaziridinones, **1**, undergo oxidation–reduction and rearrangement reactions in the presence of substituted hydrazines. Reaction of di-*t*-butyldiaziridinone, **1a**, with 1,2-di-*t*-butylhydrazine, **2a**, affords 1,3-di-*t*-butylurea and azobis-2-methyl-2-propane (major products), 1-(*t*-butylcarbamyl)-2,2-dimethylaziridine, **3a** (*i.e.*, N-*t*-butyl-2,2-dimethylaziridinecarboxamide), in 20% yield, and a few per cent of di-*t*-butylcarbodiimide. In the reaction of di-*t*-butyldiaziridinone, **1a**, with 1,2-di-*t*-amylhydrazine, **2b**, and of di-*t*-amyldiaziridinone, **1b**, with 1,2-di-*t*-butylhydrazine, **2a**, azo product comes from hydrazo reactant, excluding an addition–fragmentation mechanism (Scheme I), and supporting a hydrogen-transfer mechanism for the reduction of diaziridinone to the urea. The rearrangement reaction, **1** → **3**, is favored by increasing lability of hydrogen β to nitrogen in the diaziridinone: **1b** and **2a** afford 1-(*t*-amylcarbamyl)-2,2,3-trimethylaziridine (77%) and the urea (7%); di-2-methyl-3-phenyl-2-propyl)diaziridinone, **1c**, and **2a** afford 99% 1-(2-methyl-3-phenyl-2-propylcarbamyl)-2,2-dimethyl-3-phenylaziridine, **3c**. N-*t*-Butyl-N′-(2-methyl-3-phenyl-2-propyl)diaziridinone and **2a** afford the corresponding urea (50%) and 1-(*t*-butylcarbamyl)-2,2-dimethyl-3-phenylaziridine, **3d** (50%). In the absence of the hydrazines, the diaziridinones are stable under the reaction conditions in the presence or absence of products, indicating that the hydrazines are true catalysts for the rearrangement reaction. Low hydrazine concentrations favor rearrangement reaction over reduction of diaziridinone. A decrease in either the size or the number of substituents on the hydrazine increases the rate of reaction and decreases the aziridinecarboxamide/urea ratio; even **1c** goes largely to the urea in the presence of 1,2-dimethylhydrazine. Tetramethylhydrazine is ineffective with **1a** and **1b**, but effects the isomerization of **1c** → **3c** (at a substantially slower rate than di-*t*-butylhydrazine). The results are discussed (eq 4–8) in terms of initial hydrogen atom transfer to oxygen of diaziridinone with N–N cleavage. Intermolecular transfer of a second hydrogen to this species leads to the urea; intramolecular hydrogen abstraction (6-center) followed by cyclization leads to an azacyclopropylcarbinyl radical, convertible into rearrangement product **3** by hydrogen atom transfer to an acceptor.

In the preceding paper[1a] the synthesis and a number of reactions of diaziridinones (**1**) were described. Reaction of diaziridinone **1a** with hydrazines was shown to depend markedly on the nature of the hydrazine. Reaction of **1a** with hydrazine afforded carbohydrazide *via* nucleophilic attack on carbonyl carbon (eq 1). Reaction of **1a** with phenylhydrazine afforded 1,3-di-*t*-butylurea, benzene, and nitrogen (eq 2). In this paper, the results of an examination of the reaction of diaziridinones with substituted hydrazines are described.



1a, R = $(CH_3)_3C$–
b, R = $CH_3CH_2C(CH_3)_2$–
c, R = $C_6H_5CH_2C(CH_3)_2$–



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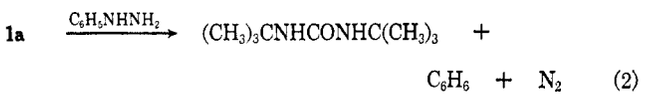
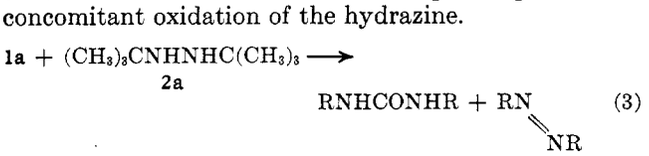


(2)

Results and Discussion

The over-all result of oxidation–reduction is a general reaction of hydrazines with **1a**. 1,1-Dimethylhydrazine, hydrazobenzene, and 1,2-di-*t*-butylhydrazine all effect the reduction of **1a** to the corresponding urea with concomitant oxidation of the hydrazine.



(3)

An early objective of this study was to ascertain whether the over-all oxidation–reduction sequence of eq 3 was initiated by nucleophilic attack on carbonyl carbon by the hydrazine (addition–fragmentation) or by a process involving hydrogen transfer from the hydrazine to the diaziridinone (Scheme I).

The distinction was sought in two "crossover" experiments: reaction of di-*t*-butyldiaziridinone with di-*t*-amylhydrazine and reaction of di-*t*-amyldiaziridinone with di-*t*-butylhydrazine.

1a, R = *t*-butyl **2a**, R′ = *t*-butyl
b, R = *t*-amyl **b**, R′ = *t*-amyl

Products	1a + 2b	1b + 2a
RNHCONHR	64	17
R′N=NR′	80[a]	30[a]
R′NHCONHR′	0	0
RN=NR	<0.4	<0.4

[a] The higher per cent of azo compound compared with urea is due to some air oxidation of reactant hydrazine.

In both experiments virtually all of the azo compound comes from the hydrazo reactant. These results exclude the addition–fragmentation sequence of Scheme I.

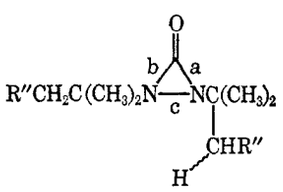
Although no "crossover" occurs, the yield of urea is considerably lower from **1b** than from **1a**. In large part, this reaction follows a different path; the major product is an isomer, **3b**, of diaziridinone **1b**. Examination of the di-*t*-butyldiaziridinone–di-*t*-butylhydrazine reaction also revealed the presence of a product, **3a**, isomeric with diaziridinone **1a**.

(1) (a) Part II: F. D. Greene, J. C. Stowell, and W. R. Bergmark, *J. Org. Chem.*, **34**, 2254 (1969). (b) Financial support from the National Science Foundation (Grant No. GP-5527) is gratefully acknowledged.

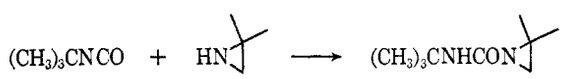
$$1 + 2a \longrightarrow RNHCONHR + t\text{-BuN=N-}t\text{-Bu} + 3$$

1a → 3a	$C_9H_{18}N_2O$	Ir 3440, 1695 cm^{-1} Nmr 1.28 (6 H, singlet), 1.38 (9 H, singlet), 2.07 (2 H, singlet), 5.03 (1 H, broad)
1b → 3b	$C_{11}H_{22}N_2O$	Ir 3440, 1690 cm^{-1} Nmr 0.85 (3 H, triplet, J = 7.5 Hz), 1.12 (3 H, doublet, J = 6 Hz), 1.16 (6 H, singlet), 1.23 (6 H, singlet), 1.58 (2 H, quartet, J = 7.5 Hz), 2.32 (1 H, quartet, J = 6 Hz), 4.82 (1 H, broad)

The isomerization is seen to involve the change of a C–H bond in the reactant to an N–H bond in the product with cleavage of bond a, b, or c of the diaziridinone, and formation of a new bond between the methylene carbon and one of the atoms of the N_2CO group. Of the large number of possible structures for



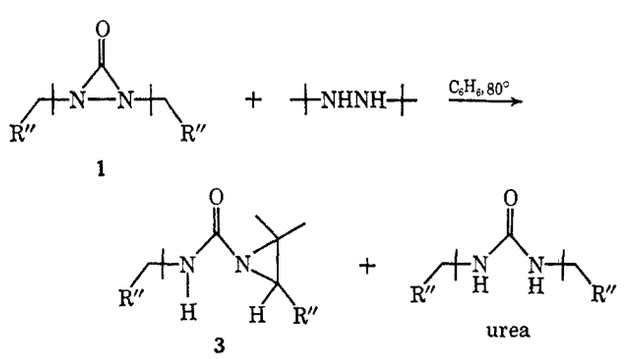
3, the physical data, coupled with the sensitivity of **3** to acid and to heat, were suggestive of the aziridinecarboxamide[2] structure, confirmed by synthesis from 2,2-dimethylaziridine and *t*-butyl isocyanate. From the reaction of **1b** with **2a** only one of the two possible aziridinecarboxamides was obtained, the one with a 2,2,3-trimethylaziridinyl moiety, **3b**.



3a

The reaction of di-*t*-butyldiaziridinone with 1,2-di-*t*-butylhydrazine also affords di-*t*-butylcarbodiimide in 7% yield. Carbodiimides were not observed as products from the reactions of diaziridinones **1b** or **1c** with the hydrazines.

Consideration of the Diaziridinone Rearrangement Reaction. A. Effect of Structure of Diaziridinone.



1

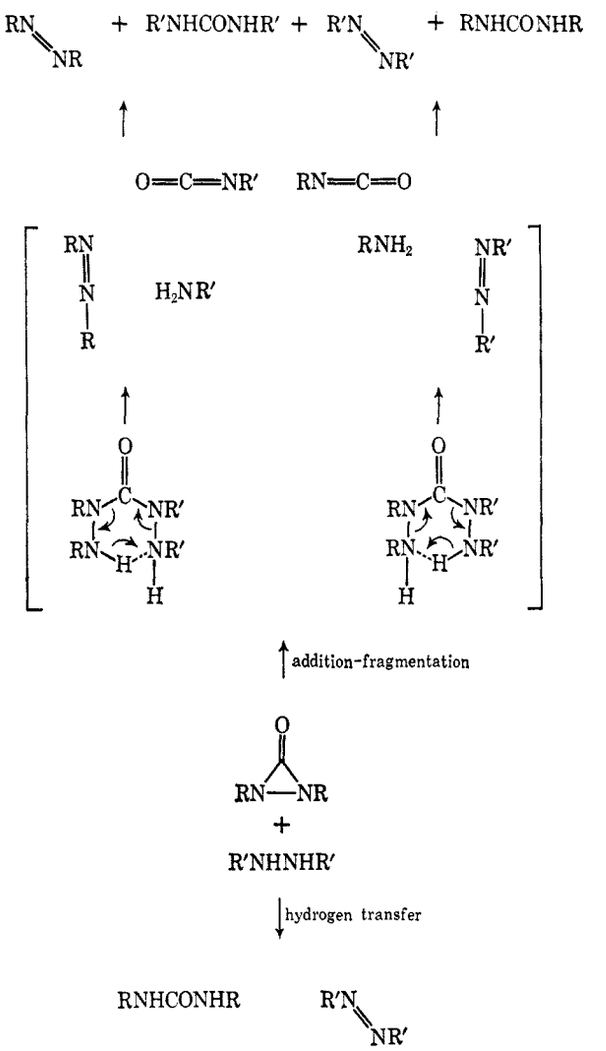
3 urea

1	Yield, % 3	Yield, % Urea	Time, hr
a, R″ = H	20	56	264
b, R″ = CH_3	77	7	18
c, R″ = C_6H_5	99	0	6

The change in character of C–H bonds that are β to the nitrogen from methyl to methylene to benzyl results in a marked increase in the rate of disappearance of diaziridinone and in an increase in the amount of reaction proceeding to the rearrangement product.

(2) H. W. Heine, *Angew. Chem. Intern. Ed. Engl.*, **1**, 528 (1962).

SCHEME I



B. Role of the Hydrazine.—In the absence of the hydrazine diaziridinones **1a–c** are stable in refluxing benzene over time periods severalfold longer than needed for the hydrazine–diaziridinone reactions. This stability of the diaziridinones is also observed when they are heated in the presence of the products of the hydrazine–diaziridinone reactions. Thus the isomerizations of **1a–c** to **3a–c** are not simple thermal reactions of the diaziridinones, but are reactions in which the hydrazines (or species derived therefrom) are true catalysts.

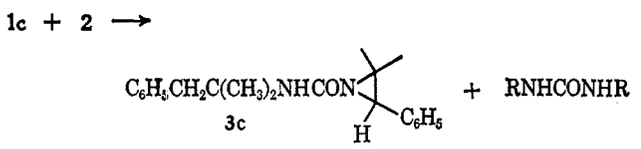
C. Effect of Concentration of the Hydrazine.

$$1a + 2a \xrightarrow[80°]{C_6H_6} 3a + t\text{-BuNHCONH-}t\text{-Bu}$$

Mole fraction 1a	Mole fraction 2a	Yield, % 3a	Yield, % *t*-Bu-NHCONH-*t*-Bu
0.08	0.92	0	85
0.1	0.08	20	56
0.1	0	No reaction	

The products and the product ratio are dependent on hydrazine, lower hydrazine concentrations favoring the isomerization reaction.

D. Effect of Structure of the Hydrazine.



Hydrazine 2	Conditions	Yield, % 3c	Yield, % Substd urea
t-BuNHNH-*t*-Bu	6 hr, 80°	99	0
$CH_3NHNHCH_3$	20 min, 25°	3	80
$(CH_3)_2NNHCH_3$	1.5 hr, 80°	65	25

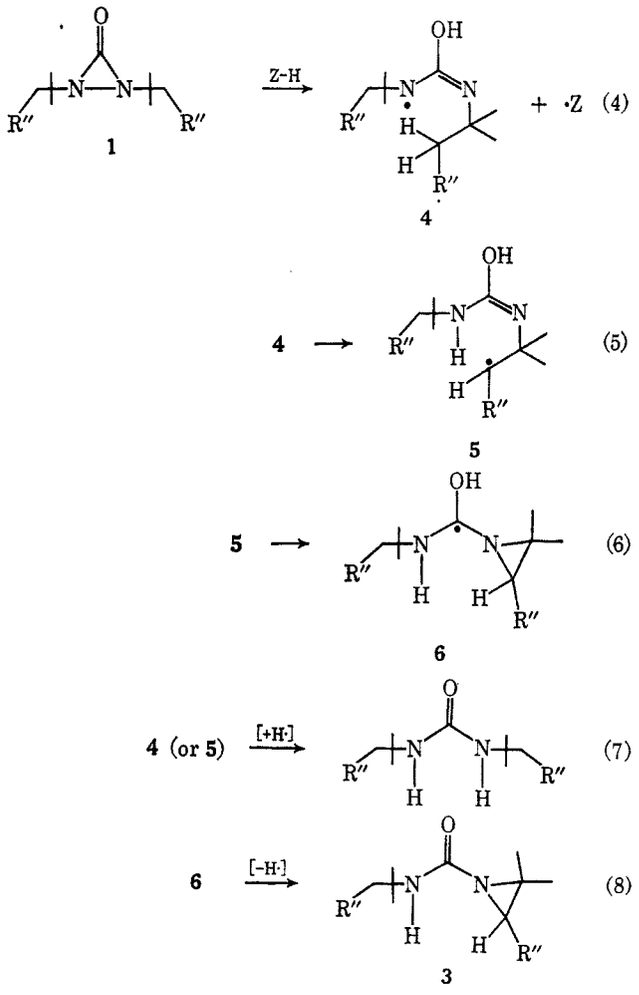
The rate of reaction and the competition between reduction and isomerization of diaziridinone are strongly dependent on the substituents on the hydrazine. Secondly, some urea is formed from the trimethylhydrazine indicating that the reduction reaction may proceed in successive single-hydrogen transfer steps.

Consideration of Hydrogen Transfer *vs.* Electron Transfer Mechanisms.—Conversion of diaziridinone into the corresponding urea obviously requires hydrogen transfers. Does the conversion of diaziridinone into the rearrangement product **3** *require* an N–H bond in the hydrazine or does it proceed by species such as a change-transfer complex between diaziridinone and the hydrazine, or by a radical anion chain mechanism? Di-*t*-butyldiaziridinone is unaffected by prolonged heating with tetramethylhydrazine although it reacts with 1,2-dimethylhydrazine at a moderate rate at room temperature and with 1,2-di-*t*-butylhydrazine with heating to give di-*t*-butylurea and **3a**. Di-*t*-amyldiaziridinone also is unaffected by prolonged heating with tetramethylhydrazine although it is largely converted into **3b** by warming with 1,2-di-*t*-butylhydrazine. Di(2-methyl-3-phenyl-2-propyl)-diaziridinone **1c** *is* converted into **3c** by heating with tetramethylhydrazine but at a rate that is 50-fold slower than with trimethylhydrazine.

If a charge-transfer complex[3] or full electron-transfer mechanism[3] were operative, one might expect a large increase in rate with increase in polarity of solvent.[4] The rough rate of disappearance of di-*t*-butyldiaziridinone in the presence of 1,2-di-*t*-butylhydrazine was severalfold faster in benzene than in *t*-butyl alcohol. The rate of disappearance of diaziridinone **1c** in the presence of tetramethylhydrazine was severalfold faster in *t*-butyl alcohol than in benzene, but little or no reaction took place between these reactants in acetonitrile (of the same *Z* value,[5] 71.3, as *t*-butyl alcohol).

These results do not provide support for mechanisms proceeding through charge-transfer complexes or radical anions for the rearrangement of diaziridinones **1a–c** to **3a–c** when the hydrazine possesses an N–H bond. The results do, however, point to a need for further study of the effect of electron donors on the diaziridinones.

Interpretation.—Of a large number of mechanisms we have considered, we favor the sequence outlined in eq 4–8: (a) the intramolecular hydrogen abstraction is depicted by nitrogen rather than by oxygen;[6–8] (b) the intramolecular hydrogen abstraction is *via* a six-atom transition state for which many examples are known,[9] and the selectivity in this abstraction is the expected one of benzyl C–H > methylene > methyl;[10] (c) the carbon radical formed by the intramolecular hydrogen abstraction is presented with only one suitable cyclization opportunity, affording an azacyclopropylcarbinyl radical,[11] **6**. The reader may verify for himself that initial hydrogen transfer to nitrogen requires more complicated mechanisms involving intramolecular abstraction by oxygen and/or hydrogen tautomerizations prior to ring closure.



A further point of interest concerns the reaction of the unsymmetrical diaziridinone, 1-*t*-butyl-2-(2-methyl-3-phenyl-2-propyl)diaziridinone, **1d**, with 1,2-di-*t*-butylhydrazine. This reaction affords only one of the two

(3) E. M. Kosower in "Progress in Physical Organic Chemistry," Vol. 3, S. G. Cohen, A. Streitwieser, Jr., and R. W. Taft, Ed., Interscience Publishers, New York, N. Y., 1965, p 81.

(4) E. M. Kosower and M. Mohammad, *J. Amer. Chem. Soc.*, **90**, 3271 (1968).

(5) E. M. Kosower, *J. Chim. Phys.*, **61**, 230 (1964).

(6) Amide radical intramolecular hydrogen abstractions are usually formulated this way (see ref 7), and a theoretical discussion on this point has been presented (ref 8). Experimental evidence on abstraction of hydrogen by N *vs.* O in amide radicals is slender, however.

(7) See R. S. Neale, N. L. Marcus, and R. G. Schepers, *J. Amer. Chem. Soc.*, **88**, 3051 (1966), and references cited therein.

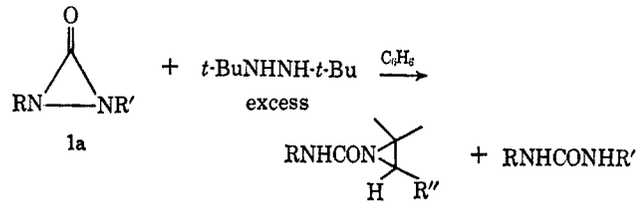
(8) E. Hedaya, R. L. Hinman, V. Schomaker, S. Theodoropulos, and L. M. Kyle, *ibid.*, **89**, 4875 (1967).

(9) See M. Akhtar in "Advances in Photochemistry," Vol. 2, W. A. Noyes, Jr., G. S. Hammond, and J. N. Pitts, Jr., Ed., Interscience Publishers, New York, N. Y., 1964.

(10) W. A. Pryor, "Free Radicals," McGraw-Hill Book Co., Inc., New York, N. Y., 1966, Chapter 12.

(11) For information on cyclopropylcarbinyl radicals, see L. K. Montgomery and J. W. Matt, *J. Amer. Chem. Soc.* **89**, 6556 (1967), and references cited therein.

possible rearrangement products *and an equal amount of the urea.* At first thought, these findings might

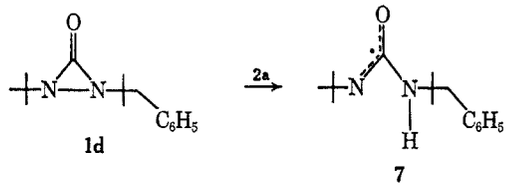


1a

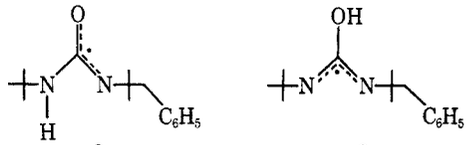
3

	Yield, % 3 (R'')	Urea
1a, R = R' = *t*-butyl	~0 (H)	~90
1d, R = *t*-butyl R' = $C_6H_5CH_2C(CH_3)_2$–	~50 (C_6H_5)	~50
1c, R = R' = $C_6H_5CH_2C(CH_3)_2$–	~99 (C_6H_5)	~0

be considered to provide evidence for initial transfer of hydrogen from the hydrazine to nitrogen of the diaziridinone forming **7** and **8** in equal amounts, rather than to oxygen forming **9**, on the grounds that it is easier to rationalize the conversion of **8** into the rearrangement product **3d** and **7** into the urea than to account for the formation of **3d** and the urea *in equal amounts* from **9**.

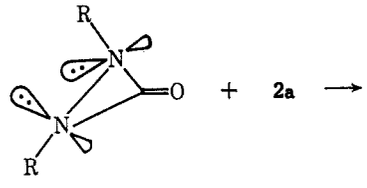


1d **7**

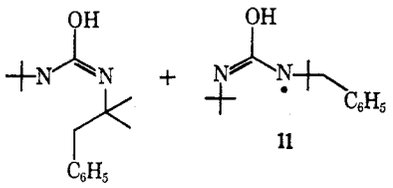


8 **9**

However, we believe that these findings are, indeed, more simply explained by initial transfer of hydrogen to oxygen. The physical evidence indicates a ground state for diaziridinones in which the substituents on the nitrogen atoms are in a *trans* orientation.[1a] Consider the transfer of hydrogen to diaziridinone with resultant disrotatory ring opening[12] to give **10** and **11**.



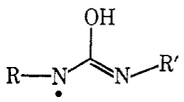
1d



10 **11**

(12) R. Hoffmann and R. B. Woodward, *Accounts Chem. Res.*, **1**, 17 (1968).

These species are shown with the odd electron in a localized orbital with the understanding that the lone pair on the nitrogen which has the odd electron is in a p orbital conjugated with the adjacent carbon–nitrogen double bond.[8] Alternatively, the lone pair might be localized and the odd electron delocalized. The following conclusions are not dependent on a choice between these alternate representations of the radicals. The formation of the urea from **11** (in 50% yield based on **1d**) and the formation of the rearrangement product **3d** from **10** (in 50% yield based on **1d**) are then the expected results (a) if **10** and **11** are formed in approximately equal amounts from reaction of **1d** with **2a** and (b) if the rates of intramolecular hydrogen abstraction (leading to rearrangement product from **10**) and intermolecular hydrogen abstraction (leading to the urea from **11**) are faster than the rates of interconversion (by rotation around the C–N bonds or by nitrogen inversion) of **10**, **11**, and **12**.



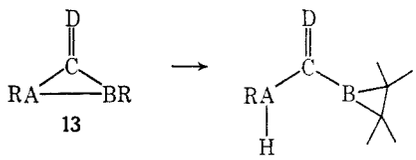
12

Many questions remain, such as the degree of chain character in the isomerization reaction (eq 9 *vs.* eq 10).

$$6 + \text{RNHN}\dot{\text{R}} \longrightarrow 3 + \text{RNHNHR} \quad (9)$$

$$6 + 1 \longrightarrow 3 + 4 \quad (10)$$

It will also be of interest to ascertain whether this type of isomerism occurs in other three-ring systems. Efforts to effect this type of change with *trans*-di-*t*-butylcyclopropanone[13] have been unsuccessful. Bond energy considerations are suggestive of decreasing driving force for the isomerization reaction as one goes from diaziridinones (**13**, A = B = N; C = C; D = O) to aziridinones (**13**, A = N; B = C = C; D = O) to cyclopropanones (**13**, A = B = C = C; D = O).



13

Experimental Section

All melting points of 1,3-di-*t*-butylurea were taken in tubes sealed under vacuum. Infrared spectra are reported in cm^{-1} with the following notations: vs, very strong intensity; s, strong; m, medium; w, weak; b, broad; sh, shoulder; and sp, sharp. Nuclear magnetic resonance spectra were determined at 60 Mc; signals are reported in parts per million (ppm) downfield from tetramethylsilane. Gas–liquid partition chromatographic analyses (glpc) were performed with helium carrier gas and thermal conductivity detectors with the following columns: column A [a 6 ft × 0.25 in. aluminum tube packed with 20% (w/w) silicone oil "SE- 0" on a 60/80 mesh Chromosorb W diatomite support employing a flow rate of 65 cc/min]; column C [a 6 ft × 0.25 in. aluminum tube packed with silicone oil DC 200 on a 80/100 mesh Chromosorb P diatomite washed to a pH 8]. All identifications (unless otherwise noted) of glpc components were made by the identity with an authentic sample of both retention time and ir spectrum of a collected sample. All quantitative analyses were made by the internal standardization method unless otherwise noted. A sessment of error

(13) J. F. Pazos and F. D. Greene, *J. Amer. Chem. Soc.*, **89**, 1030 (1967).

was obtained in several of the analytical series by matching two or more standard solutions against each other. Error was found to be ±2%. (In one series the results are known to only ±10% as reported in the text.)

1-*t*-Butyl-3-(2-methyl-3-phenyl-2-propyl)urea was prepared by reaction of 2-methyl-3-phenyl-2-propylamine in hexane with *t*-butyl isocyanate. After standing overnight, the hexane was removed and the white solid was recrystallized from hexane or ethanol–water: yield 39.0 g (91%); mp 164.5–165.0°; nmr ($CDCl_3$) δ 1.29 (s, 6 H), 1.37 (s, 9 H), 3.08 (s, 2 H), 4.0 (broad, 2 H), and 7.29 (s, 5 H); ir ($CHCl_3$) 3440 (b, NH), 2970, 1678 (s, urea), and 1515 cm^{-1} (m).

Anal. Calcd for $C_{15}H_{24}N_2O$: C, 72.54; H, 9.74; N, 11.28. Found: C, 72.56; H, 10.01; N, 11.07.

1-*t*-Butyl-2-(2-methyl-3-phenyl-2-propyl)diaziridinone, 1d, was prepared in 72% yield by the method described previously:[1a] bp 86–92° (0.02 mm); $n^{24.8}D$ 1.4480; nmr ($CDCl_3$) δ 1.12 (s, 6 H), 1.21 (s, 9 H), 2.86 (s, 2 H), and 7.22 (s, 5 H); ir ($CHCl_3$) 3075 (w, Ph), 2945, 2985 (s), 1870 (s, C=O) and 1600 cm^{-1} (w, Ph).

Anal. Calcd for $C_{15}H_{22}N_2O$: C, 73.12; H, 9.00; N, 11.37. Found: C, 72.85; H, 8.95; N, 11.32.

Diaziridinones 1a–c were described in part II.[1a]

1,2-Di-*t*-amylhydrazine was prepared by adding 9.90 g (50 mmol) of diaziridinone **1b** slowly under a nitrogen atmosphere to 100 ml of 15% aqueous HCl with rapid stirring. The solution was stirred an additional 5 min after the turbidity and evolution of gas ceased. The solution was cautiously made basic with 40% aqueous NaOH solution and extracted under nitrogen with a 300-ml portion of pentane. The pentane extract was dried (nitrogen atmosphere) by passing through a short column of anhydrous K_2CO_3. Removal of the pentane afforded 7.02 g (82%) of crude hydrazine which was purified for use by preparative glpc (column E, 155°). The purified hydrazine had ir (CCl_4) 3225 (b), 1455 (m), 1375 (m), 1175 cm^{-1}(m); nmr (CCl_4) 0.95 (s, 6 H, J = 7.5 Hz), 0.98 (s, 12 H), 1.39 (quartet, 4 H, J = 7.5 Hz), 2.71 (broad singlet, 2 H); $n^{22.5}D$ 1.4316.

Anal. Calcd for $C_{10}H_{24}N_2$: C, 69.70; H, 14.04; N, 16.26. Found: C, 70.03; H, 13.84; N, 16.33.

2,2′-Dimethyl-2,2′-azobutane.—A mixture of 1,2-di-*t*-amylhydrazine (1.00 g, 5.8 mmol), yellow mercuric oxide (10.00 g, 46.2 mmol), and 10 ml of water was shaken vigorously in a stoppered flask for 1 hr and allowed to stand overnight. The mixture was then extracted with three 15-ml portions of pentane which were combined and dried (K_2CO_3). Removal of the pentane afforded 0.838 g (84%) of crude azo compound which showed only pentane as an impurity in glpc (column E, 155°) and after purification by preparative glpc had ir (CCl_4) 1465, 1360, 1380 cm^{-1}; nmr (CCl_4) 0.81 (triplet, 6 H, J = 7.5 Hz), 1.10 (s, 12 H), 1.68 (quartet, 4 H, J = 7.5 Hz); $n^{23.0}D$ 1.4175.

Anal. Calcd for $C_{10}H_{22}N_2$: C, 70.52; H, 13.02; N, 16.45. Found: C, 70.76; H, 12.96; N, 16.55.

The oxidation did not occur when a dry pentane solvent was used with no aqueous phase.

1-(*t*-Butylcarbamyl)-2,2-dimethylaziridine (N-*t*-butyl-2,2-dimethyl-1-aziridinecarboxamide), 3a, was prepared by adding a solution of 3.97 g (40.0 mmol) of *t*-butyl isocyanate in 60 ml of pentane over a 30-min period to a stirred solution of 2.90 g (40.8 mmol) of 2,2-dimethylaziridine[14] in pentane over nitrogen in a dry apparatus at room temperature. After an additional 30 min of stirring, the solution was evaporated to dryness under vacuum affording 5.976 g (35.1 mmol, 88%) of crude aziridinecarboxamide **3a**, mp 67–74° (ir not distinguishable from pure **3a**), which was fractionally sublimed at 50–70° (0.02 mm). Five recrystallizations from pentane of the first sublimed fraction gave pure **3a** with constant mp 77.5–78.5°; ir (CCl_4) 3440 (sp), 1695 (s), 1495 (s), 1455, 1390, 1380, 1370, 1340 cm^{-1}; nmr (CCl_4, all singlets) 1.28 (6 H), 1.38 (9 H), 2.07 (2 H), 5.03 (NH).

Anal. Calcd for $C_9H_{18}N_2O$: C, 63.49; H, 10.65; N, 16.46. Found: C, 63.26; H, 10.64; N, 16.46.

Elution of 200 mg of **3a** over 10 g of silica gel with 60 ml of ethyl acetate afforded 166 mg of material, mp 123–170°. Similarly glpc of **3a** (column A) gave only high-melting mixtures from the exit port. The use of adsorbants (Norit) and ethyl acetate, methylene chloride, and methanol as recrystallization solvents were not effective in purification of **3a**. The compound is decomposed by heating and by the action of acids (probably converted into an oxazoline).[2]

N-(2-Methyl-3-phenyl-2-propyl)-2,2-dimethyl-3-phenyl-1-aziridinecarboxamide, 3c, was prepared by the above method in 86% yield from 2,2-dimethyl-3-phenylaziridine[15] and 2-methyl-3-phenyl-2-propyl isocyanate:[16] mp of **3c**, 118–119°; nmr ($CDCl_3$) δ 0.87 (s, 3 H), 1.21 (s, 3 H), 1.24 (s, 3 H), 1.31 (s, 3 H), 2.74 (d, 1 H, J = 13 Hz), 3.13 (d, 1 H, J = 13 Hz), 3.30 (s, 1 H), 4.70 (broad singlet, 1 H), and 7.06, 7.07 (d, 10 H); ir (CCl_4) 3440 (s), 3020 (m), 1690 (s), and 1600 cm^{-1} (w). The magnetic nonequivalence of the methylene hydrogens and the adjacent methyls of the $C_6H_5CH_2C(CH_3)_2$– group is of special interest in view of their separation by 5 (and 4) bonds from the chiral center in the aziridine moiety.

Anal. Calcd for $C_{21}H_{26}N_2O$: C, 78.22; H, 8.13; N, 8.69. Found: C, 78.44; H, 8.26; N, 8.73.

N-*t*-Butyl-2,2-dimethyl-3-phenyl-1-aziridinecarboxamide, 3d, was prepared from the aziridine[14] and *t*-butyl isocyanate in hexane: mp 174–175° (from benzene); nmr ($CDCl_3$) δ 0.97 (s, 3 H) 1.35 (s, 12 H), 3.50 (s, 1 H), 5.0 (broad, 1 H), and 7.27 (s, 5 H); ir ($CHCl_3$), 3420 (NH), 1680 (amide), and 2950 cm^{-1}.

Anal. Calcd for $C_{15}H_{22}N_2O$: C, 73.13; H, 9.00; N, 11.37. Found: C, 73.15; H, 9.25; N, 11.42.

Reaction of 1,2-Di-*t*-butylhydrazine, 2a, with Di-*t*-butyldiaziridinone, 1a. A. In Benzene.—A solution of 2.292 g (13.46 mmole) of **1a**, 1.511 g (10.48 mmol) of **2a**, and 1.695 g of bromobenzene (internal standard) in 10 ml of oxygen-free benzene was refluxed for 11.0 days under a dry nitrogen atmosphere. The course of the reaction was followed by glpc (column A, 112°) and ir. The products, 2,2′-dimethyl-2,2′-azopropane and di-*t*-butylcarbodiimide,[17] were identified and isolated from glpc [the carbodiimide was also indicated by ir (2100-cm^{-1} doublet) in the reaction solution]. Upon cooling, the reaction mixture contained a mat of fine, white needles which were collected by filtration and washed with a small amount of pentane, dried at 0.02 mm, and identified as 1.203 g (6.98 mmol, 52%) of 1,3-di-*t*-butylurea by mp 236–237°, mmp 236.5–237°, and an ir spectrum identical with that of an authentic sample. The combined filtrate and washings were evaporated to dryness (0.02 mm, 12 hr) affording white crystals, 534 mg, mp 72–105°, purified by combinations of fractional sublimation and fractional recrystallization from pentane to afford 153 mg of 1-(*t*-butylcarbamyl)-2,2-dimethylaziridine, **3a**, identified by mp 79–81°, mmp 79–81°; ir, nmr spectra, and chromatographic behavior were all identical with synthetic sample data. The crude material was assayed by a glpc method using column A (110°), indicating 19% of **3a** and an additional 4% of the urea. Under the conditions chosen the aziridinecarboxamide **3a** gives a single peak of reproducible retention time even though collection of the eluted peak affords no **3a** but only high-melting material. Furthermore, the response factor (relative to the urea for example) is abnormally low suggesting that this peak does not represent all the injected material. The use of these glpc conditions as a method for quantitative analysis for both **3a** and the urea was found to be valid, however, by the cross-checkings of standard solutions. Error of the measurements was found to be ±10% of the actual value. Analysis of the original reaction solution by this method gave the following results. After 1 day, 58% of **1a** and 55% of **2a** had been consumed; 49% 2,2′-dimethyl-2,2′-azopropane had formed. After 7 days, 90% of **1a** and 83% of **2a** had been consumed; 87% azo compound and 7% di-*t*-butylcarbodiimide had formed. After 11 days, 99% of **1a** and 89% of **2a** had been consumed; 94% azo compound and 7.5% carbodiimide had formed. The yield (see above) of di-*t*-butylurea was 56%, of 1-*t*-butylcarbamyl-2,2-dimethylaziridine **3a** was 20%. The ir of the product mixture had weak absorption at 2250 cm^{-1} (isocyanate). A solution of **1a** (0.8 M) and **2a** (0.092 M) in benzene gave the urea (11% based on **1a**, 92% based on **2a**) and **3a** (5.6% based on **1a**). A solution of **1a** (0.5 mmol) and **2a** (5.5 mmol) was heated (sealed tube) without added solvent for 45 hr at 86°, giving the urea in 85% yield and no **3a**.

B. In *t*-Butyl Alcohol.—A solution of 2.545 g (14.9 mmol) of **1a** and 1.529 g (10.6 mmol) of **2a** in 10.0 ml of *t*-butyl alcohol (distilled from sodium and deoxygenated with dry nitrogen)

(14) K. C. Campbell, A. H. Sommers, and B. K. Campbell, "Organic Syntheses," Coll. Vol. III, John Wiley & Sons, Inc., New York, N. Y., 1955, p 148.

(15) S. J. Brois, *J. Org. Chem.*, **27**, 3532 (1962).

(16) British Patent 613,111 (Nov 23, 1948); *Chem. Abstr.*, **43**, 5800*h* (1949).

(17) E. Schmidt and M. Seefelder, *Ann.*, **571**, 83 (1951).

was refluxed for a total of 25 hr under nitrogen: diaziridinone (determined by ir) remaining after 3.5 hr, 42%; 14.5 hr, 15%; and 20 hr, 11%. Analysis for products by the above methods gave 60% di-*t*-butylurea and 12% **3a**.

Aliquots of a solution of 17.8 mg (0.105 mmol) of **1a** and 79.0 mg (0.547 mmol) of **2a** in 1.00 ml of benzene (dried over Na, distilled on a Teflon spinning-band column and deoxygenated with nitrogen) were sealed in capillary tubes and heated at 86.0 ± 0.01°. The tubes were opened periodically and the diaziridinone concentration was measured by ir. A solution of 18.6 mg (0.109 mmol) of **1a** and 78.0 mg (0.540 mmol) of **2a** in 1.00 ml of *t*-butyl alcohol (distilled from Na) was also examined in the same way. Time for 20% reaction: benzene, 14 hr; *t*-butyl alcohol, 70 hr. Time for 40% reaction: benzene, 23 hr; *t*-butyl alcohol, 120 hr.

Reaction of Diaziridinone 1a with 1,2-Dimethylhydrazine.—A solution of 737 mg (12.3 mmol) of 1,2-dimethylhydrazine[18] and 2.41 ml (2.10 g, 12.3 mmol) of **1a** in 60 ml of fresh, dry ether was refluxed for 36 hr under nitrogen. During this time fine, white crystals deposited. Use of an apparatus to measure gas evolution indicated that none was employed. A single compound was found in the liquid phase on glpc analysis (column C, 25°), azomethane, 76.5%. [The standard azomethane solution for quantitative determination was prepared by oxidizing a known amount of 1,2-dimethylhydrazine with mercuric oxide in ether and 2,3-dimethylbutane (internal standard) solution.] Analysis for products indicated 80% di-*t*-butylurea, no **3a**, and a small amount of an unidentified material with ir 1655 cm^{-1}.

Reaction of Di-*t*-butyldiaziridinone (1a) with Hydrazobenzene.—A solution of 2.15 g (11.7 mmol) of hydrazobenzene and 2.00 g (11.7 mmol) of **1a** in 50 ml of benzene was refluxed under nitrogen for 115 hr, monitoring by ir. The resulting mixture was cooled and filtered; the collected needles were washed and dried to yield 1.547 g of 1,3-di-*t*-butylurea. Analysis of the filtrate by uv at λ 319 indicated 89% azobenzene. Work-up of the filtrate afforded 112 mg of the urea (total yield of urea, 1.66 g, 78%) and 1.55 g (73% yield) of azobenzene, isolated by chromatography on alumina, mp 67–68°, mmp 67–68°.

"Crossover Experiments." A. Reaction of 1,2-Di-*t*-amylhydrazine, 2b, with Di-*t*-butyldiaziridinone, 1a.—Hydrazine **2b** (purified by preparative glpc), 148 mg (0.851 mmol), and 134 mg (0.786 mmol) of diaziridinone **1a** (along with a bromobenzene internal standard) were sealed in a tube and allowed to stand 21 days at room temperature (heating 12 hr at 100° gives the same results) to produce a mass of fine, white crystals with interstitial liquid phase. The liquid phase was examined by glpc (column A, 112°) and found to contain 2,2′-dimethyl-2,2′-azobutane and starting hydrazine **2b**. Recovery of the **2b** as such or as the azo compound was 98%. A certain amount of the hydrazine would air oxidize on handling the reaction mixtures which was accounted for by blanks. A minor component, 2,2′-dimethyl-2,2′-azopropane, was observed in a 0.34% yield. (There was not a sufficient amount of it for an ir spectrum; its identification is based on retention time alone.) The solid fraction from the reaction was collected by centrifugal filtration, washed five times with 250-μl portions of pentane, and dried 12 hr *in vacuo* to give white crystals [84 mg (64% yield), identified as 1,3-di-*t*-butylurea by mp 237.4–238°, mmp 238.5–239.5° (mmp with **3b**, 222–224.5°)], and an ir spectrum identical with that of authentic 1,3-di-*t*-butylurea (but different from 1,3-di-*t*-amylurea). An ir spectrum of the liquid phase showed a very small amount (1–2%) of starting **1a**.

B. Reaction of 1,2-Di-*t*-butylhydrazine, 2a, with Di-*t*-amyldiaziridinone, 1b.—A solution of 1.516 g (10.50 mmol) of **2a** and 2.105 g (10.60 mmol) of **1b** in 10 ml of benzene was refluxed under a nitrogen atmosphere for 18 hr. Analysis by ir showed no diaziridinone remaining after this time. Bromobenzene was added and the solution analyzed by glpc (column A, 112°). A 33% yield of 2,2′-dimethyl-2,2′-azopropane was found. Azo-hydrazine recovery (mmoles of 2,2′-dimethyl-2,2′-azopropane found + mmoles of **2a** remaining/mmoles of starting **2a**) was 102%. The residual solid obtained after removal of volatile components under vacuum was separated by fractional recrystallization from pentane into two components, 135 mg (6.8%) of di-*t*-amylurea,[1a] mp 209–213°, and 1.61 g (76.5%) of a substance which after purification by several sublimations and recrystallizations from pentane was identified as 1-(*t*-amylcarbamyl)-2,2,3-trimethylaziridine, **3b**: mp 90–91°; nmr (see Results); ir (CCl_4) 3440 (sp), 1690 (s), 1495 (s), 1385 (sh), 1380 (m), 1365 (w), 1255 cm^{-1} (m); mol wt (osmotic, benzene), 195 (calcd 198).

Anal. Calcd for $C_{11}H_{22}N_2O$: C, 66.62; N, 11.15; N, 14.13. Found: C, 66.34; H, 11.08; N, 14.13.

Control experiments with hydrazine **2a** alone in benzene indicated some oxidation to azo compound.

When this reaction was run under conditions parallel to those of the reaction of hydrazine **2b** with diaziridinone **1a**, the results were essentially the same as those described above with the following exceptions: the experiment at room temperature for 20 days (**2a**, 1.00 mmol; **1b**, 0.933 mmol) resulted in a 17% yield of di-*t*-amylurea and 68% aziridinecarboxamide **3b**. A minor component, 2,2′-dimethyl-2,2′-azobutane (0.4%), was also observed (identification based on retention time only).

When 150 mg of **1b** was heated for 12 hr at 100° in a sealed tube, very little decomposition was observed; a very small 1690-cm^{-1} band appeared and a slight yellow color was noted. No significant change in diaziridinone concentration was observed from the absorbance of the carbonyl group in the ir.

Reaction of Di(2-methyl-3-phenyl-2-propyl)diaziridinone, 1c, with 1,2-Di-*t*-butylhydrazine, 2a.—A solution of 666 mg (2.065 mmol) of **1c** and 404 mg (2.80 mmol) of **2a** in 10 ml of benzene was refluxed for 18 hr under a positive pressure of nitrogen. Analysis by ir indicated no diaziridinone remained. Removal of the volatile components left a residue which when triturated with pentane afforded a total of 623 mg (94% yield) of a single component (tlc), mp 107–110°. Recrystallization from isooctane afforded pure 1-[(2-methyl-3-phenyl-2-propyl)carbamyl]-2,2-dimethyl-3-phenylaziridine, **3c**, mp 117.5–118.5°, identical with the synthetic sample. Diaziridinone **1c** under these reaction conditions undergoes no change when **2a** is absent.

A solution of 293 mg (0.91 mmol) of **1c** and 41 mg (0.28 mmol) of **2a** in 5 ml of oxygen-free benzene was degassed and heated in a sealed tube at 80° for 6 hr. The volatile components were removed under vacuum (reaching 0.02 mm for 12 hr) to leave a residue of 290 mg of **3c** (0.90 mmol, 99%), mp 115–116°, which when recrystallized from isooctane gave 276 mg, mp 116.5–117.5°. The rate of this reaction was not retarded by the use of rigorously purified benzene (distilled on a Teflon spinning-band column).

Reaction of Diaziridinone 1c with 1,2-Dimethylhydrazine.—A solution of 800 mg (2.48 mmol) of **1c** and 0.207 mg (180 mg, 3.00 mmol) of 1,2-dimethylhydrazine[18] in 10 ml of oxygen-free benzene over a nitrogen atmosphere at room temperature became warm, was diaziridinone free within 20 min (ir), and deposited fine, white crystals. The crystals were collected by filtration and the filtrate was reduced to dryness under vacuum. Trituration with a total of 35 ml of isooctane afforded an insoluble fraction which was combined with the crystalline precipitate and identified as 633 mg (1.95 mmol, 79%) of di(2-methyl-3-phenyl-2-propyl)urea by mp 179–180.5°, mmp 179–181° (authentic sample mmp 179.5–182°),[1a] and an ir spectrum identical with an authentic one. A total of 20 mg (0.062 mmol, 2.5%) of a substance was crystallized from a pentane solution of the soluble fraction; it was identified as aziridinecarboxamide **3c**, ir spectrum virtually identical with that of authentic **3c**.

Reaction of Diaziridinone 1c with Trimethylhydrazine.—A solution of 324 mg (1.00 mmol) of **1c** and 358 mg (4.83 mmol) of trimethylhydrazine[19] in 10 ml of purified and deoxygenated benzene was allowed to stand 22 hr at room temperature with little reaction occurring (ir). The solution was then refluxed for 1.5 hr after which no diaziridinone remained. The resulting pale yellow solution was evaporated to dryness affording a white solid. The solid afforded a soluble and an insoluble fraction upon trituration with 25 ml of hot isooctane. The former, 203 mg (0.63 mmol, 63%), was identified as aziridinecarboxamide **3c** by mp 108.5–112.5°, mmp 110–115.5° (when recrystallized from pentane, mp 116.5–117.5°, mmp 117–118°), and an ir spectrum identical with an authentic one. The latter fraction, 88 mg (0.27 mmol, 27%), was identified as di(2-methyl-3-phenyl-2-propyl)urea, mp 175.5–178.5°, mmp 178.5–180.5°, and an ir spectrum identical with an authentic one.[1a]

Reaction of Diaziridinone 1c with Tetramethylhydrazine.—A solution of 342 mg (1.095 mmol) of **1c** and 115 μl (88 mg, 1.00

(18) Liberated from the hydrochloride (Aldrich Chemical Co.) and purified by the method of H. H. Halt, "Organic Syntheses," Coll. Vol. II, John Wiley & Sons, Inc., New York, N. Y., 1943, p 211.

(19) R. T. Beltrami and E. R. Bissell, *J. Amer. Chem. Soc.*, **78**, 2467 (1956).

mmol) of tetramethylhydrazine[18] in 5 ml of benzene was sealed in tubes under vacuum and heated at 80 ± 3° for 50 hr. The course of the reaction was followed by ir. The resulting solution was evaporated under vacuum to an oil which crystallized. The crystals, 355 mg (1.10 mmol, quantitative), were identified as aziridinecarboxamide **3c** by mp 110–113°, mmp 113–116°, and an ir spectrum identical with that of an authentic sample. Diaziridinone **1c** was totally unchanged on heating in benzene alone for 50 hr at 80°.

A solution of 330 mg (1.02 mmol) of **1c** and 115 μl (88 mg, 1.00 mmol) of tetramethylhydrazine in 5 ml of *t*-butyl alcohol (distilled from sodium metal) was degassed, sealed in a tube, and heated for 6 hr at 80 ± 3°. The resulting solution was evaporated; the crystals, 295 mg (0.92 mmol, 89%), were identified as **3c** by mp 110–113°, mmp 114–116°, and ir spectrum identical with an authentic one. When **1c** was heated alone in *t*-butyl alcohol for 6 hr 20% was consumed. (A band in the 1675–1700-cm^{-1} region appeared which roughly accounted for all the **1c** consumed.)

A solution of 323 mg (1.00 mmol) of **1c** and 88 mg (1.00 mmol) of tetramethylhydrazine in 5.00 ml of acetonitrile (dried over P_2O_5 and distilled on a Teflon spinning-band column) was heated for a total of 18 hr at 80° in one large and several small capillary tubes to produce yellow solutions. A small amount of **1c** was consumed. Approximately the same degree of consumption was observed when **1c** was heated in acetonitrile in the absence of the hydrazine.

Attempted Reaction of Di-*t*-amyldiaziridinone, 1b, with Tetramethylhydrazine.—A solution of 30 μl (23 mg, 0.26 mmol) of tetramethylhydrazine[19] and 45 mg (0.23 mmol) of diaziridinone **1b** in 2.0 ml of benzene was heated at 80° for 18 hr in tubes sealed under vacuum. Analysis of ir spectra indicated no consumption of diaziridinone or appearance of any new bands. No reaction was observed by ir when a solution of equimolar amounts of each component was heated at 80° for 12 hr, without solvent.

Reaction of 1-*t*-Butyl-2-(2-methyl-3-phenyl-2-propyl)diaziridinone, 1d, with Di-*t*-butylhydrazine 2a.—A solution of 0.876 g (3.56 mmol) of **1d**[1a] and 0.573 g (3.98 mmol) of **2a** in 5 ml of benzene was degassed, sealed in tubes, and heated at 80°. Reaction was complete in 2.5 hr. Separation of the crystals and recrystallization from benzene afforded 0.32 g (1.31 mmol, 41%) of 1-*t*-butyl-2-(2-methyl-3-phenyl-2-propyl)urea: mp 164–165°, mmp 163–165°, ir and nmr identical with authentic spectra. Fractional recrystallization of material from the filtrates afforded 0.19 g (0.77 mmol, 24%) of N-*t*-butylcarbamyl-2,2-dimethyl-3-phenylaziridine, **3d**, mp 175–176°, identical in ir and nmr with the synthetic sample. Analysis by nmr of an aliquot of the original solution of products from the reaction showed that 50% urea and 50% **3d** were formed. A parallel experiment with 0.172 g (0.70 mmol) of **1d** and 0.185 g (1.28 mmol) of **2a** in 4 ml of benzene assayed by nmr indicated 47% urea and 53% **3d**.

Reaction of Diaziridinone 1d with 1,2-Dimethylhydrazine.—A solution of 0.29 g (1.18 mmol) of **1d** and 0.24 g (4.0 mmol) of 1,2-dimethylhydrazine was degassed, sealed, and left at 25° for 24 hr. Removal of volatile components left 0.287 g (98% yield) of 1-*t*-butyl-3-(2-methyl-3-phenyl-2-propyl)urea, mp 163–165°, identical in ir and nmr with authentic material. A solution of **1d** (0.015 *M*) and 1.2-dimethylhydrazine (0.033 *M*) in benzene afforded the urea in 87% and **3d** in 13% yield.

Registry No.—1-*t*-Butyl-3-(2-methyl-3-phenyl-2-propyl)urea, 19656-66-7; **1d**, 19656-67-8; 1,2-di-*t*-amylhydrazine, 19713-61-2; 2,2′-dimethyl-2,2-azobutane, 19694-12-3; **3a**, 19656-68-9; **3b**, 19656-69-0; **3c**, 19656-70-3; **3d**, 19656-77-0.

Diaziridinones. IV.[1] Formation by Condensation of Alkyl Isocyanide with Nitrosoalkane. Evidence for a Carbodiimide N-Oxide

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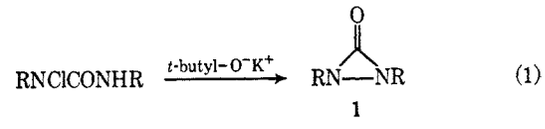
Reaction of *t*-butyl isocyanide with 2-methyl-2-nitrosopropane, **5**, at 70° (1:1, neat) affords di-*t*-butyldiaziridinone, **1a** (90%), di-*t*-butylcarbodiimide, **6a** (10%), and 2-methyl-2-nitropropane, **7**. The ratio of **6a**:**1a** increases with increasing concentrations of nitrosoalkane **5**; products **6a** and **7** are formed in comparable amounts over wide variation in the ratio of reactants. Reaction of *t*-butyl isocyanide with nitrosoalkane **5** in the presence of phenyl isocyanate affords two 1:1:1 adducts, **9** and **10**. Reaction of isopropyl isocyanide and nitrosoalkane **5** affords 1-*t*-butyl-2-isopropyldiaziridinone, **1b**, carbodiimide **6b**, and nitroalkane **7** in the absence of phenyl isocyanate, and affords 1:1:1 adduct **8** in the presence of phenyl isocyanate. The results are discussed in terms of condensation of alkyl isocyanide with nitrosoalkane to afford carbodiimide N-oxide **3**. This intermediate may rearrange (presumably *via* oxaziridinimine **2**) to diaziridinone **1**, may react with nitrosoalkane leading to carbodiimide **6** and nitroalkane **7**, or may react with phenyl isocyanate to afford the 1:1:1 adducts.

We recently described a synthesis (eq 1) of diaziridinones **1** and outlined some of the physical and chemical properties of this system.[2] The method of synthesis was only successful when R was a tertiary alkyl group. In a search for other methods of synthesis of **1** we have considered approaches based on the possibility of ring–chain isomerism in the diaziridinone system (eq 2). If diaziridinones were more stable than forms such as **2**, **3**, or **4**, then compounds of structure **1** might be made *via* syntheses of these other species. Inspection of **2** and **3** reveals the possibility of their formation from an isocyanide and a nitroso compound. This paper describes the results of a study of reaction of 2-methyl-2-nitrosopropane with alkyl isocyanides.[3]



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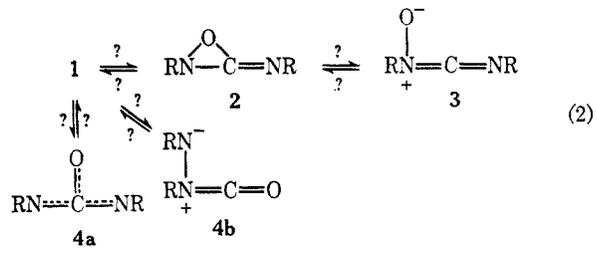

(2)

(1) (a) Part III: F. D. Greene, W. R. Bergmark, and J. G. Pacifici, *J. Org. Chem.*, **34**, 2263 (1969); (b) Financial support from the National Science Foundation (Grant No. GP 5527) is gratefully acknowledged.

(2) F. D. Greene, J. C. Stowell, and W. R. Bergmark, *J. Org. Chem.*, **34**, 2254 (1969).

(3) For a report of the reaction of nitrosotrifluoromethane with methyl isocyanide, see S. P. Makarov, *et al.*, *Dokl. Akad. Nauk SSSR*, **142**, 596 (1962).