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# The Thermal Rearrangement and Degradation of 2,3-Bis(alkylimino)oxetane

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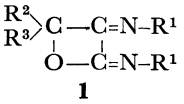
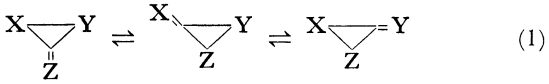
The thermal rearrangement of 2,3-bis(alkylimino)oxetane (**1**) was investigated. At 200°C, 2,3-bis(secondary alkylimino)oxetane was converted into 3-imidazolin-5-one (**8**). 2,3-Bis(tertiary alkylimino)oxetane was stable at 200°C, but it was rearranged at 300°C to a cyclobutanone derivative (**18**). A mechanism involving the β-lactam intermediate (**12**) (**17**) formed by the Chapman rearrangement of **1** was proposed.

This paper will describe the thermal rearrangement and the accompanying decomposition of 2,3-bis(alkylimino)oxetane (**1**).



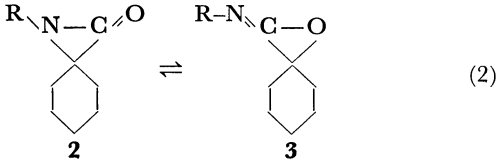
**1**

The rearrangement of **1** constitutes a significant extension of the molecular rearrangement of methylenecyclopropane derivatives with hetero atoms in their framework (Eq. (1)), which has recently attracted considerable attention.[1,2]



(1)

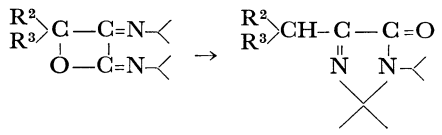
Among several examples, the tautomeric interconversion of three-membered α-lactam (**2**) and imino-oxirane (**3**) reported by Sheehan and Lengyel[2] (Eq. (2)) is taken to be especially closely related to the present study.



**2** **3** (2)

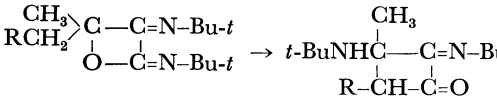
Further, the imino-oxirane–lactam rearrangement has been assumed in the following scheme of the $BF_3 \cdot OEt_2$-catalyzed reactions of isocyanides[3] with carbonyl compounds[4] to produce 2,3-diimino-oxetane (**1**).[3-7] The formation of a by-product, **7**, in the acid-catalyzed reaction of isocyanide with carbonyl compounds has been explained by a process involving the molecular rearrangement of **4** to **5** (Scheme 1).

The course of the thermal rearrangement of **1** is dependent upon the nature of alkyl groups ($R^1$) attached to the imino nitrogen atoms. When $R^1$ is a secondary alkyl, the rearrangement occurs at 200°C and takes the course of Eq. (3), in which the migration of the secondary hydrogen atom of one alkyl group is involved:



(3)

When $R^1$ is a tertiary alkyl in **1**, rearrangement requires a higher temperature of 300°C and involves the migration of the hydrogen of the alkyl group of $R^2$ or $R^3$ (Eq. (4)):



(4)

1) J. A. Deyrup and R. B. Greenwald, *Tetrahedron Lett.*, **1966**, 5091; J. A. Deyrup, M. M. Vestling, W. V. Hagan, and H. Y. Yun, *Tetrahedron*, **25**, 1467 (1969).

2) J. C. Sheehan and I. Lengyel, *J. Amer. Chem. Soc.*, **86**, 746 (1964); J. C. Sheehan and I. Lengyel, *ibid.*, **86**, 1356 (1964); J. C. Sheehan and I. Lengyel, *Angew. Chem. Internat. Ed.*, **7**, 25 (1968).

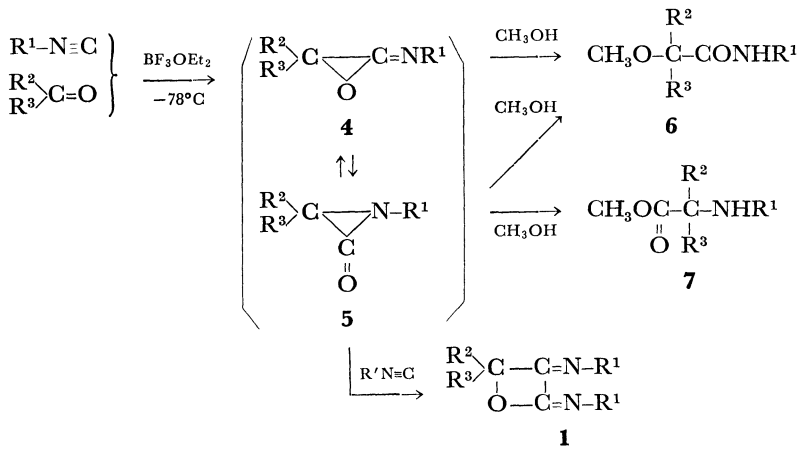
3) T. Saegusa, N. Taka-ishi, and H. Fujii, *Polymer Lett.*, **5**, 779 (1967).

4) T. Saegusa, N. Taka-ishi, and H Fujii, *Tetrahedron*, **24**, 3795 (1968)

5) H. J. Kabbe, *Angew. Chem.*, **80**, 406 (1968).

6) H. J. Kabbe, *Chem. Ber.*, **102**, 1404 (1969).

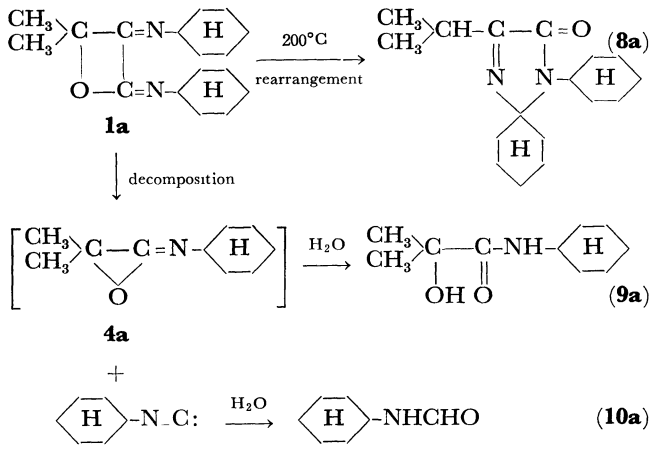
7) B. Zeeh, *Tetrahedron Lett.*, **1969**, 113.



Scheme 1

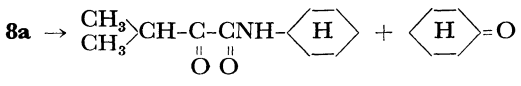
## Results and Discussion

When **1a** ($R^1$=  , $R^2$=$R^3$=Me) was heated at 200°C, the rearranged compond **8a** was obtained in a yield of 43%, along with small amounts of 2-hydroxy-2-methyl-*N*-cyclohexylpropionamide (**9a**) and *N*-cyclohexylformamide (**10a**) (Scheme 2). The structure of **8a** was established on the basis of spectral analyses in addition to elemental analysis. The presence of the isopropyl group in **8a** was clearly demonstrated by the NMR spectrum. The absence of NH and OH groups was indicated by the IR spectrum. Other observations of the IR and NMR spectra as well as the results of the elemental analysis fit the structure **8a** (see Experimental Section).



Scheme 2

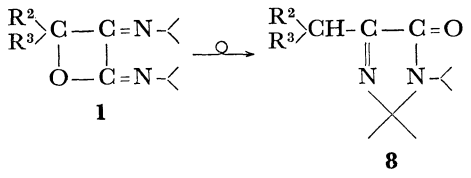
Additional support for the structure **8a** was given by acid hydrolysis, which produced an α-keto acid amide (**11**) and cyclohexanone:



**11**

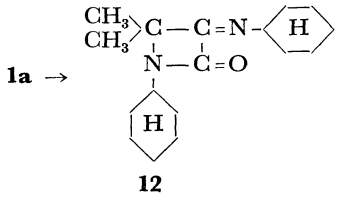
Some other homologues, **1b** ($R^1$=  , $R^2$=Me, $R^3$=Et) and **1c** ($R^1$=*i*-Pr, $R^2$=Me, $R^3$=Et), were also converted to the corresponding 3-imidazolin-5-one. The results are shown in Table 1. The employment of a solvent such as benzyl benzoate and diphenylmethane did not increase the yield of the rearranged product.

TABLE 1. REARRANGEMENT OF 2,3-BIS(SECONDARY ALKYLIMINO)OXETANE



| Compound | -< | $R^2$ | $R^3$ | Solvent | Yield of **8** (%) |
|---|---|---|---|---|---|
| **1a** | -  | $CH_3$ | $CH_3$ | — | 43 |
| **1b** | -  | $CH_3$ | $C_2H_5$ | — | 62 |
| **1c** | $-CH(CH_3)_2$ | $CH_3$ | $C_2H_5$ | — | 49 |
| **1c** | $-CH(CH_3)_2$ | $CH_3$ | $C_2H_5$ | $C_6H_5CH_2OCOC_6H_5$ | 38 |
| **1c** | $-CH(CH_3)_2$ | $CH_3$ | $C_2H_5$ | $(C_6H_5)_2CH_2$ | 37 |

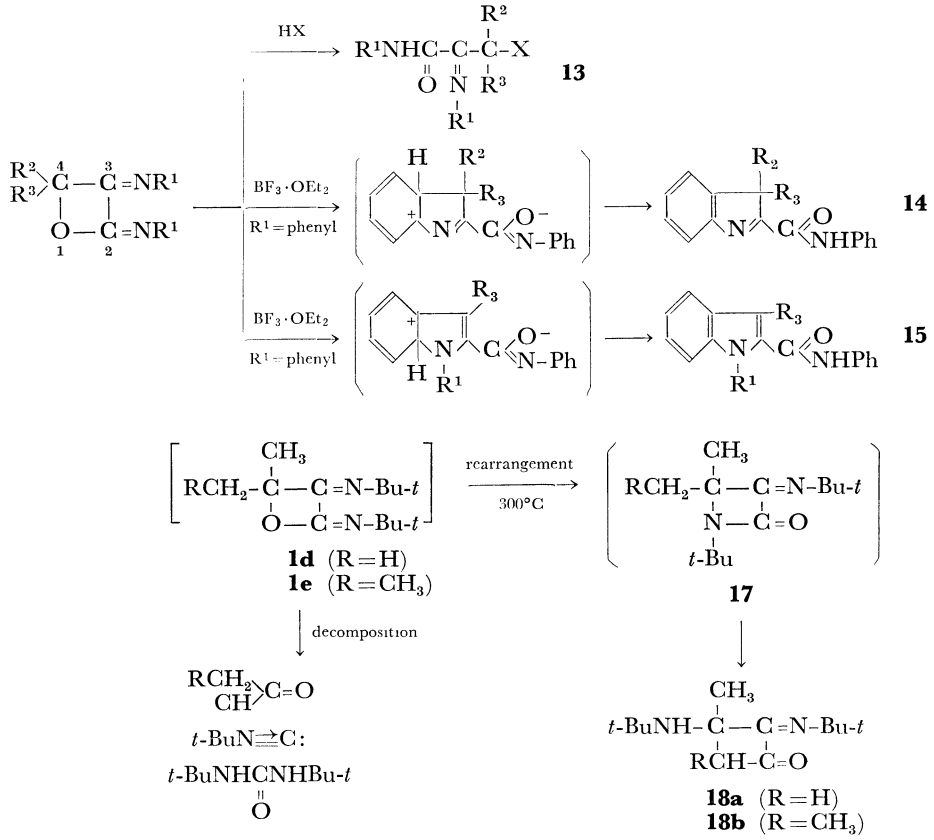
As to the reaction mechanism, the normal Chapman reaction may be thought of an as antecedent process which may produce a precursor intermediate (**12**).



**12**

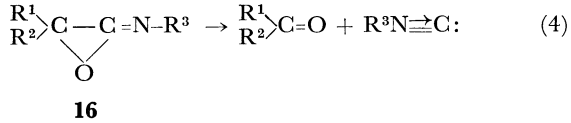
However, several attempts to isolate **12** were all unsuccessful. The structure of the product shows unequivocally the cleavage of the O–4C bond. The position of the bond-cleavage of the thermal rearrangement is the same as that of the cationic reaction of 2,3-bis-iminooxetane. The cationic ring-opening of **1** by acid, producing **13**, has been previously reported by Kabbe[8] and by us.[4] When the $R^1$ or $R^2$ of **1** is an aromatic ring, the $BF_3$-catalyzed bond-cleavage takes place at the O–4C bond

8) H. J. Kabbe, *Chem. Ber.*, **102**, 1410 (1969).



to produce indol derivatives, **14** and **15**.[9,10]

The formation of by-products of **9a** and **10a** may be explained by assuming the decomposition of **1a** into cyclohexyl isocyanide and an unstable imino-oxirane **4a**. The hydrolytic cleavage of **4a** affords **9a**, and the hydrolysis of cyclohexyl isocyanide gives rise to **10a**. The decomposition of **1a** depicted in Scheme 2 resembles the decomposition of imino-oxirane (**16**) to isocyanide and a carbonyl compound, as has been reported by Kagen and Lillien.[11] (Eq. (4)):



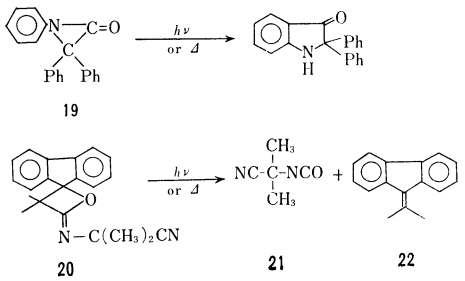
(4)

**16**

The bis(tert-alkylimino)homologue of **1** has no hydrogen at the α-carbon atom of nitrogen, and its thermal rearrangement takes a different route. At 200°C, **1d** ($R^1$=*t*-Bu, $R^2$=$R^3$=Me) is stable and does not rearrange. The rearrangement of **1d**, however, occurs at 300°C to produce **18a**. The concurrent decomposition of **1d** takes place to give *t*-butyl isocyanide, acetone, and di-*t*-butylurea.

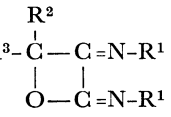
The structure **18a** was established by a study of the spectral data and by elemental analysis. The presence of a secondary amino group was indicated in both the IR and the NMR spectra. In the NMR spectrum, the appearance of two new peaks at τ 6.50 (NH) and τ 6.28 (-$CH_2$)-was taken to support the structure **18a**. Similarly, **1e** ($R^1$=*t*-Bu, $R^2$=Me, $R^3$=Et) was converted into **18b**. The acetylation of **18b** with acetyl chloride gave the *N*-acetyl derivative. This result also supports the structure of **18b**.

As to the mechanism of the rearrangement of **1d** and **1e**, the structure of the product **18** may be taken to suggest a scheme *via* an intermediate of β-lactam (**17**) which is formed by the Chapman rearrangement of **1**. The cleavage of the bond between the amide nitrogen and the carbonyl carbon atom in **17** leads to the formation of **18**. The rearrangement **1d** and **1e** may be compared with the thermal reactions of the related compounds. Sheehan has reported[12,13] the rearrangement of triphenyl-substituted α-lactam (**19**) which proceeded the analogous bond cleavage. Singer and Barlett[14] have shown the photo- and thermal-decomposition of an iminooxetan (**20**) into the corresponding isocyanate (**21**) and olefin (**22**).



9) B. Zeeh, *Tetrahedron Lett.*, **1967**, 3881; B. Zeeh, *Chem. Ber.*, **102**, 678 (1969).
10) B. Zeeh, *Angew. Chem.*, **79**, 415 (1967); B. Zeeh, *Chem. Ber.*, **101**, 1753 (1968).
11) H. Kagen and I. Lillien, *J. Org. Chem.*, **31**, 3728 (1966).
12) J. C. Sheehan and J. W. Frankenfeld, *J. Amer. Chem. Soc.*, **83**, 4792 (1961).
13) J. C. Sheehan and I. Lengyel, *J. Org. Chem.*, **28**, 3252 (1963).
14) L. A. Singer and P. D. Barlett, *Tetrahedron Lett.*, **1964**, 1887.

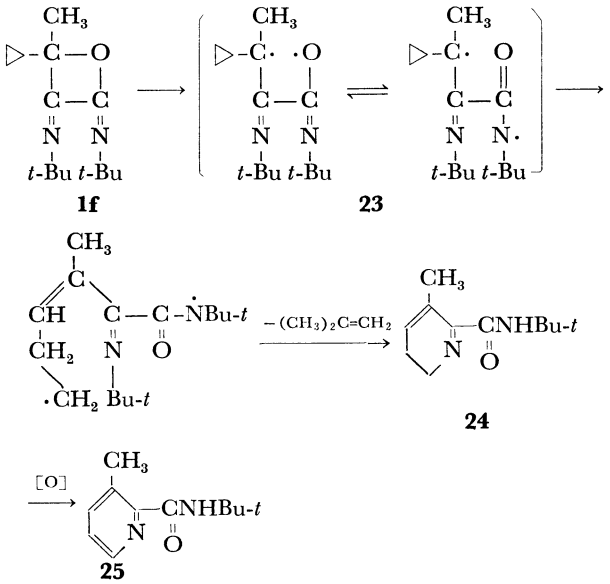
Table 2. Characterizations of 2,3-bis(alkylimino)oxetanes



| Compd | $R_1$ | $R_2$ | $R_3$ | Bp C°/mmHg | Formula | Anal Calcd % C | H | N | Found % C | H | N | NMR absorption, $\tau$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1b** |  | $CH_3$ | Et | 129—130/[a] | | | | | | | | m 5.9 (1H), m 6.45 (1H) s 8.52 (3H), t 9.00 (3H) |
| **1c** | *i*-Pr | $CH_3$ | Et | 78—80/12 | $C_{12}H_{22}N_2O$ | 68.53 | 10.54 | 13.32 | 68.42 | 10.69 | 13.21 | m 5.55 (1H), m 6.16 (1H) q 8.22 (2H), s 8.52 (3H) d 8.85 (6H), d 8.88 (6H) t 9.00 (3H) |
| **1d** | *t*-Bu | $CH_3$ | $CH_3$ | 94—96/32[b] | $C_{13}H_{24}N_2O$ | 69.60 | 10.78 | 12.49 | 69.44 | 10.95 | 12.37 | s 8.50 (6H), s 8.58 (9H) s 8.68 (9H) |
| **1e** | *t*-Bu | $CH_3$ | Et | 74—76/7 | $C_{14}H_{26}N_2O$ | 70.54 | 10.99 | 11.75 | 70.79 | 11.03 | 11.66 | q 8.25 (2H), s 8.57 (3H) s 8.64 (9H), s 8.70 (9H) t 9.05 (3H) |
| **1f** | *t*-Bu | $CH_3$ |  | 110/18 | $C_{15}H_{26}N_2O$ | 71.95 | 10.47 | 11.19 | 71.66 | 10.23 | 11.27 | s 8.45 (3H), s 8.60 (9H) s 8.70 (9H), m 8.8—9.6 (5H) |

a) Distilled with partial degradation. b) Lit, bp 76°C/10 mmHg.[6]

A bis(alkylimino)oxetane with a cyclopropane ring at 4-C (**1f**, $R^1$=*t*-Bu, $R^2$=Me, $R^3$=cyclopropyl) rearranged *via* different way, one involving the cleavage of the cyclopropane ring. The product was a picolinamide (**25**).



In the above scheme, the first step is the cleavage of the carbon oxygen bond at the same position as that of Scheme 2. The ring-opening of the cyclopropane ring of **23** followed by the cyclization of the resulting radical, with the elimination of isobutene, will produce a dihydropicolinamide derivative (**24**), whose dehydrogenation then gives rise to **25**.

## Experimental

*Materials.* 2,3-Bis(cyclohexylimino)-4,4-dimethyloxetane[4] (**1a**) and 2,3-bis(*t*-butylimino)-4,4-dimethyloxetane[6] (**1d**) have been previously reported. The other iminooxetanes were prepared by a procedure described previously.[4] The properties of the iminooxetanes are shown in Table 2.

*Thermal Rearrangement of 2,3-Bis(cyclohexylinino)-4,4-dimethyloxetane* (**1a**). At 200°C, 1.1 g (4 mmol) of **1a** was heated for 7 hr and then subjected to distillation. From the distillate, bp 150—153°C/8 mmHg, 1-cyclohexyl-4-isopropyl-2,2-pentamethylene-3-imidazolin-5-one(**8a**) was obtained in a yield of 43%.

Found: C, 73.07; H, 10.51; N, 9.76%. Calcd for $C_{17}H_{28}N_2O$: C, 73.87; H, 10.21; N, 10.13%. IR spectrum (neat): 1680 ($\nu_{C=O}$) and 1625 ($\nu_{C=N}$) $cm^{-1}$; NMR spectrum ($CDCl_3$): $\tau$ 8.78 (doublet, 6H, $(\underline{CH_3})_2CH$–), 7.8—9.0 (complex, 20H, $-CH_2-$ of cyclohexyl ring), 7.2—7.8 (broad multiplet, 1H, –CH– of the cyclohexyl ring), 7.05 (multiplet, 1H, $(CH_3)_2\underline{CH}$–). The by-products, *N*-cyclohexylformamide (**10a**) and 2-hydroxy-2-methyl-*N*-cyclohexylpropionamide (**9a**), were isolated by preparative glpc in yields of 4% and 8% respectively. **9a** was identified by a comparison of the glpc retention time and IR spectrum with those of an authentic sample prepared according to the method of Hagedorn.[15]

*Hydrolysis of 1-Cyclohexyl-4-isopropyl-2,2-pentamethylene-3-imidazolin-5-one (8a).* A solution of 1.4 g (5 mmol) of **8a** in 20 ml of ethanol saturated with hydrochloric acid was refluxed for 1 day. After the ethanol has then been evaported, the reaction mixture was treated with aqueous sodium hydrogencarbonate and extracted with methylene chloride. The methylene chloride extract was washed with water and then subjected to glpc analysis. Cyclohexanone and *N*-cyclohexyl-3-methyl-2-oxobutyramide (**11**) were obtained in yields of 70% and 78% respectively.

Found: C, 66.30; H, 9.76; N, 6.82%. Calcd for $C_{11}H_{19}NO_2$: C, 66.97; H, 9.71; N, 7.10%. IR spectrum (neat): 1725 ($\nu_{C=O}$) and 1665 ($\nu_{N-C=O}$) $cm^{-1}$, NMR spectrum ($CDCl_3$):

15) I. Hagedorn and U. Eholzer, *Chem. Ber.*, **98**, 936 (1965).

$\tau$ 8.85 (doublet, 6H, $(\underline{CH_3})_2CH$), 7.8—9.0 (complex, 11H, cyclohexane ring protons) 6.4 (multiplet, 1H, $(CH_3)_2\underline{CH}$), 3.2 (broad multiplet, 1H, $\underline{NH}$).

*1-Cyclohexyl-4-*sec*-butyl-2,2-pentamethylene-3-imidazolin-5-one (8b).* **8b** was obtained in a yield of 62% by the thermal rearrangement of 2,3-bis(cyclohexylimino)-4-ethyl-4-methyloxetane (**1b**), bp 155—160°C/3 mmHg. IR spectrum (neat): 1685 ($\nu_{C=O}$) and 1630 ($\nu_{C=N}$) $cm^{-1}$; NMR spectrum ($CDCl_3$); $\tau$ 9.10 (triplet, 3H, $\underline{CH_3}CH_2$–), 8.78 (doublet, 3H, $\underline{CH_3}CH$), 7.5—9.0 (complex, 21H, cyclohexane ring protons), 7.25 (multiplet, 1H, $CH_3\underline{CH}$); Mass spectrum: *m/e* 290 ($M^+$).

*4-*sec*-Butyl-1-isopropyl-2,2-dimethyl-3-imidazolin-5-one (8c).* **8c** was obtained in a yield of 49% by the thermal rearrangement of 2,3-bis(isopropylimino)-4-ethyl-4-methyloxetane (**1c**), bp 89—90°C/18 mmHg.

Found: C, 68.25; H, 10.82; N, 13.07%. Calcd for $C_{12}H_{22}N_2O$: C, 68.53; H, 10.54; N, 13.32%. IR spectrum (neat): 1680 ($\nu_{C=O}$) and 1625 ($\nu_{C=N}$) $cm^{-1}$; NMR spectrum ($CDCl_3$): $\tau$ 9.08 (triplet, 3H, $\underline{CH_3}CH_2$), 8.77 (doublet, 3H, $\underline{CH_3}CHCH_2$-$CH_3$), 8.55 (singlet, 6H, N–$C(CH_3)_2$–N), 8.53 (doublet, 6H, $(\underline{CH_3})_2CH$), 8.35 (multiplet, 2H, $CH_3\underline{CH_2}$–CH), 7.22 (multiplet, 1H, $CH_3\underline{CH}CH_2CH_3$), 6.25 (multiplet, 1H, $(CH_3)_2\underline{CH}$).

*Thermal Rearrangement of 2,3-Bis(*t*-butylimino)-4,4-dimethyloxetane (1d).* At 300—350°C, 2 g (9 mmol) of **1d** was heated for 1 hr and then distilled. The volatile material trapped by a dry ice-methanol bath, was shown to be a mixture of acetone and *t*-butyl isocyanide by a study of the glpc and NMR spectra. From the distillation condensate, bp 118°C/12 mmHg, 3-*t*-butylamino-2-*t*-butylimino-3-methylcyclobutanone (**18a**) was obtained by means of preparative glpc in a yield of 30%.

Found: C, 68.94; H, 10.55; N, 12.66%. Calcd for $C_{13}H_{24}N_2O$: C, 69.60; H, 10.78; N, 12.49%. IR spectrum (neat): 3350 ($\nu_{NH}$) and 1665 ($\nu_{C=O}$ and $\nu_{C=N}$) $cm^{-1}$; NMR spectrum ($CDCl_3$): $\tau$ 8.77 (singlet, 9H, *t*-Bu), 8.55 (singlet, 9H, *t*-Bu), 8.00 (singlet, 3H, $CH_3$), 6.50 (singlet, 1H, NH), 6.28 (singlet, 2H, $CH_2$), Mass spectrum: *m/e* 224 ($M^+$). From the residue, 1,3-di-*t*-butylurea was obtained in a yield of 11%; it was identified by a comparison of IR and NMR spectra with those of the authentic sample.

*3-*t*-Butylamino-2-*t*-butylimino-3,4-dimethylcyclobutanone (18b).* **18b** was obtained in a yield of 64% by the thermal rearrangement of 2,3-bis(*t*-butylimino)-4-ethyl-4-methyloxetane (**1e**), bp 135°C/12 mmHg.

Found: C, 69.97; H, 11.39; N, 11.60%. Calcd for $C_{14}H_{26}N_2O$: C, 70.54; H, 10.99; N, 11.75%. IR spectrum (neat): 3350 ($\nu_{NH}$) and 1665 ($\nu_{C=O}$ and $\nu_{C=N}$) $cm^{-1}$. NMR spectrum ($CDCl_3$): $\tau$ 8.78 (singlet, 9H, *t*-Bu), 8.65 (doublet, 3H, $\underline{CH_3}CH$), 8.50 (singlet, 9H, *t*-Bu), 8.05 (singlet, 3H, $CH_3$), 6.85 (singlet, 1H, NH), 6.10 (quartet, 1H, $CH_3\underline{CH}$). Mass spectrum: *m/e* 238 ($M^+$).

*Acetylation of 3-*t*-Butylamino-2-*t*-butylimino-3,4-dimethylcyclobutanone (18b).* Into a solution of 0.5 g of **18b** (2 mmol) and 0.5 m*l* of triethylamine in 10 m*l* of ether, we stirred, drop by drop, 1 m*l* of acetyl chloride at room temperature. After standing for 20 hr, the reaction mixture was treated with aqueous sodium hydrogencarbonate. The ether layer was then subjected to glpc analysis to yield the *N*-acetylated compound quantitatively.

Found: C, 68.30; H, 10.00; N, 9.71%. Calcd for $C_{16}H_{28}N_2O_2$: C, 68.53; H, 10.07; N, 9.99%. IR spectrum (neat): 1660 $cm^{-1}$; NMR stectrum ($CDCl_3$): $\tau$ 8.58 (doublet, 3H, $\underline{CH_3}CH$), 8.57 (singlet, 9H, *t*-Bu), 8.49 (singlet, 9H, *t*-Bu), 8.21 (singlet, 3H, $CH_3$), 8.08 (singlet, 3H, $CH_3$), 5.95 (multiplet, 1H, $CH_3\underline{CH}$). Mass spectrum: *m/e* 280 ($M^+$).

N-*t*-*Butyl-3-methylpicolinic Amide (25).* At 200°C, 1 g (4 mmol) of 2,3-bis(*t*-butylimino)-4-cyclopropyl-4-methyloxetane (**1f**) was heated for 1 hr and then subjected to glpc analysis. **25** was thus obtained in a yield of 23%.

Found: C, 68.92; H, 8.64; N, 14.69%. Calcd for $C_{11}H_{16}N_2O$: C,68.72; H, 8.39; N, 14.57%. IR spectrum (neat): 3350 ($\nu_{NH}$), 1670 ($\nu_{C=O}$), and 1510 ($\nu_{NH}$) $cm^{-1}$. NMR spectrum ($CCl_4$): $\tau$ 8.52 (singlet, 9H, *t*-Bu), 7.30 (singlet, 3H, $CH_3$), 2.80 (multiplet, 1H, $\underline{H}C{=}C{-}CH_3$), 2.50 (multiplet, 1H, $\underline{H}C{=}CH{-}N$), 2.50 (broad singlet, 1H, NH), 1.70 (multiplet, 1H, $CH{=}N$). Mass spectrum: *m/e* 192 ($M^+$).