RING CONTRACTION OF A CYCLIC SEVEN-MEMBERED KETENE IMINE

Rolf Huisgen,* Elke Langhals, and Takumi Oshima

Institut für Organische Chemie der Universität München
Karlstr. 23, D-8000 München 2, Federal Republic of Germany

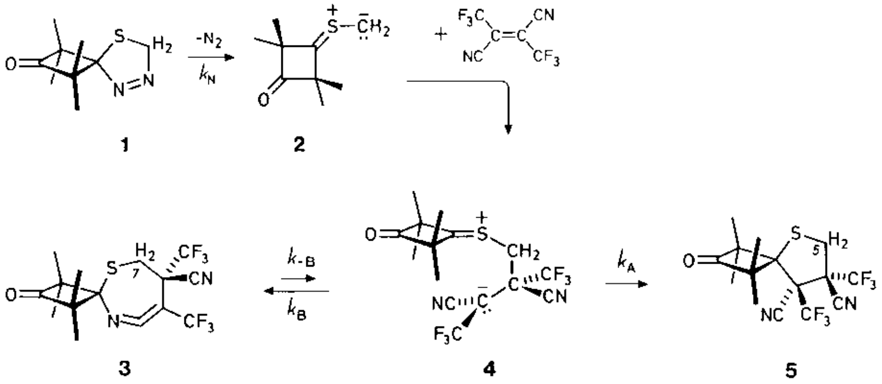
Dedicated to Professor Michael J.S. Dewar on the occasion of his seventieth birthday

Abstract - A cyclic ketene imine prepared from 2,2,4,4-tetramethyl-3-thioxocyclobutanone *S*-methylide and 2,3-bis(trifluoromethyl)fumaronitrile rearranges to the isomeric thiolane. The high dependence of the rate on solvent polarity and the steric course are in accordance with an open-chain zwitterionic intermediate.

Thiocarbonyl ylide 2 combines in situ with 2,3-bis(trifluoromethyl)fumaronitrile in $CDCl_3$ furnishing the strained 7-membered cyclic ketene imine 3 and the trans-thiolane 5 in 78:22 ratio.[1] The zwitterion 4 is an attractive precursor.

A. The Rearrangement and Its Mechanism

Although stable in the crystalline state, ketene imine 3 rearranges in solution to the thermodynamically preferred thiolane 5. The *strain-induced* reversal to the zwitterion 4 is a likely initiating step. The gauche zwitterion 4 might be distributed again in the ratio of the rate constant (k_B/k_A) until the whole material arrives at 5. Both cyclizations of 4 are exothermic, and their transition states are suppo-



sed to be reactant-like, i.e., structurally still close to 4. The net isomerization rate constants (k_{exp}) should be a function of three k values:

$$k_{exp} = k_{-B} \frac{k_A}{k_A + k_B}$$

The ring opening ($\underline{3} \rightarrow \underline{4}$ with k_{-B}) is accompanied by charge separation, and its late transition state should profit from solvent polarity. A smaller dependence on the polarity of the medium is to be expected for the partition coefficient.

The AB spectra of 7-H_2 of 3 and 5-H_2 of 5 allowed monitoring the rate by ^1H nmr spectroscopy. The rearrangement follows the first reaction order ($r > 0.99$). The half-life of the ketene imine at 60°C amounts to 101 h in cyclohexane and to 7.0 min in acetonitrile. The rate increase by 10^3 (Table 1) is in accordance with the open-chain zwitterion occurring in the rearrangement process. The relation between log k_{exp} and the empirical parameter of solvent polarity, E_T, is fair (Fig. 1).

Table 1. Solvent dependence of rearrangement rate, $\underline{3} \rightarrow \underline{5}$

Solvent	$10^6 k_{exp}$ (s^{-1}) at 60°C	and 40°C	k_B/k_A at 40°C	$10^6 k_N$ (s^{-1}) at 40°C
[D_{12}]Cyclohexane	1.94			
Carbon disulfide	4.02		2.2	
[D_6]Benzene	22.1		4.6	
[D]Chloroform	21.1		3.6	
1,2-Dichlorobenzene	33.3			
[D_8]Tetrahydrofuran	159	13.6	5.3	132
Benzonitrile	497	80.4		
[D_3]Acetonitrile	1 640			97

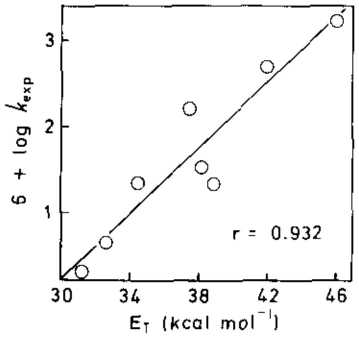
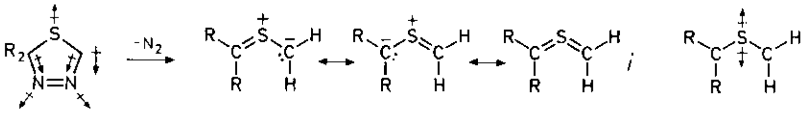


Fig. 1. Relation between rearrangement rate and solvent polarity parameter, ET

In two solvents, the rate constant k_{exp} was also measured *at 40 °C* and compared with the first-order rate constants (k_N) of generating the thiocarbonyl ylide 2 from thiadiazoline 1. Of course, the rearrangement $\underline{3} \rightarrow \underline{5}$ sets in immediately upon formation of 3. In THF at 40°C, the N_2 extrusion of 1 requires $t_{1/2}$ 87.5 min whereas the ring contraction, $\underline{3} \rightarrow \underline{5}$, takes place with $t_{1/2}$ 14.2 h, i.e., k_N is 9.7 times larger than k_{exp}. According to the rate law of consecutive first order reactions, one expects only 0.24% (1.9%) rearrangement, 3 → 5, after 20% (50%) conversion of 1. For product ratios, 3/5, at low conversion, we found next to no dependence on time within the ±2% limit of nmr analysis. Thus, *kinetically controlled* ratios (3/5 = k_B/k_A) are available for all solvents except the most polar ones. The data allow to determine the absolute rate constant of ring opening, 3 → 4, for THF at 40°C: $k_{-B} = k_{exp}\left(1 + \frac{k_B}{k_A}\right) = 13.6\ 10^{-6}\ 6.3 = 86\ 10^{-6}\ s^{-1}$.



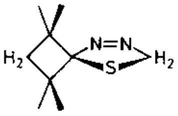
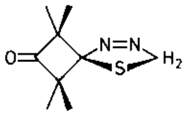
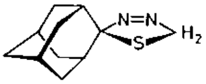
6

7

7a

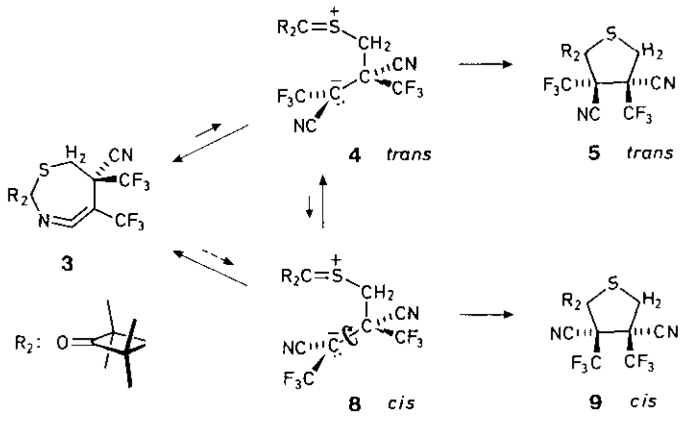
Is a small negative response of k_N to solvent polarity (Table 1) not contradictory to the formation of 1,3-dipole 2 ? 1,3-Dipoles are quadrupoles in the physicist's language and do not necessarily possess high dipole moments.[2] The resonance structures 7 of thiocarbonyl ylides show the negative charge distributed on both sides of the positive. The resulting moment leading from the sulfur down to the center of the negative charge is partially compensated by the lone pair moment on sulfur (structure 7a). The partial electric moments of thiadiazoline 6 suggest higher polarity. In fact, a modest decrease in the rate of N_2 elimination with rising solvent polarity was observed also for other 1,3,4-thiadiazolines (Table 2).

Table 2. Rate constants for the N_2 extrusion of 1,3,4-thiadiazolines in four solvents; $10^6 k_N$ (s^{-1}) at 40.0°C

			
Xylene	119	171	149
THF	114	132	128
Acetonitrile	71.3	97	107
Sulfolane		80	

B. Stereochemistry of Ring Contraction

A second stereocenter is generated in the rearrangement of 3, giving rise to diastereoisomeric thiolanes. *A priori*, the ring openings of 3 to give trans and cis zwitterion, 4 and 8, have equal chances.



In the first experiments, we observed only the ^{19}F nmr signals of the trans-thiolane 5. After long pulsing the CF_3 signals of the cis isomer 9 appeared; comparison with the ^{13}C satellites of the CF_3's of 5 allowed a quantitative analysis. When the rearrangement took place in D_3C-CN or C_6D_6 at 60°C, the thiolane mixture contained 1.8% and 1.9% of the cis configuration 9.

The steric course of the cycloaddition of 2 and 2,3-bis(trifluoromethyl)fumaronitrile [1] was reinvestigated in C_6D_6 at 80°C (10 min). Trans-and cis-thiolanes, 5 and 9, occurred in 98.4 : 1.6 ratio, along with 3. The same thiolanes appeared in a ratio of 62:38 in the cycloaddition experiment with the cis acceptor olefin indicating a lower stereospecificity. With some approximations it is calculated that a ring-opening of ketene imine 3 giving 99% trans-and 1% cis-zwitterions, 4 and 8, could be responsible for the stereochemical outcome: 1.9% 9. Van der Waals repulsion of the CF_3 groups in the cis-zwitterion 8 can be conceived as the reason for the preferred formation of the trans-zwitterion 4.

ACKNOWLEDGMENT

We thank the *Deutsche Forschungsgemeinschaft* and the *Fonds der Chemischen Industrie* for support. Our thanks are going to Mrs. *Gisela Brüntrup* for experimental help.

REFERENCES

1. R. Huisgen, E. Langhals, G. Mloston, and T. Oshima, *Heterocycles*, preceding communication.
2. R. Huisgen, "1,3-Dipolar Cycloadditions - Introduction, Survey, Mechanism" in *1,3-Dipolar Cycloaddition Chemistry*, (A. Padwa, Ed.), Vol. 1, Wiley-Interscience, New York, pp. 27-35.

Received, 8th Augsut, 1989