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ORGANOSELENIUM CHEMISTRY. MECHANISM AND STEREOCHEMISTRY OF N,N-DIMETHYLBENZENESELENENAMIDE ADDITION TO DIMETHYL ACETYLENEDICARBOXYLATE. CONFIGURATIONALLY LABILE OLEFINS.

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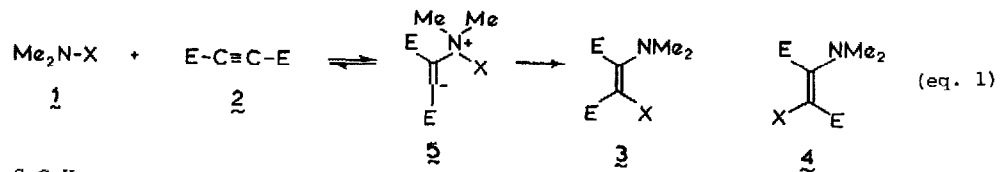
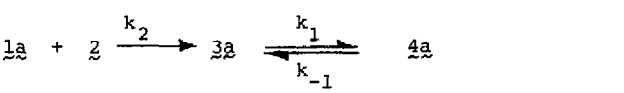
N,N-Dialkylbenzeneselenenamides react with good Michael acceptors to form β-dialkylamino α-phenylseleno carbonyl compounds.[1] A mechanism for this reaction involving Michael addition followed by intramolecular selenenylation was proposed. We report here the results of a study of this reaction using N,N-dimethylbenzeneselenenamide (1a) and dimethyl acetylenedicarboxylate (2, E = CO_2CH_3). The mechanism proposed (eq. 1) predicts the formation of only one stereoisomer (the maleate derivative 3a).



(eq. 1)

(a) X = SeC_6H_5
(b) X = Se-p-CF_3-C_6H_4
(c) X = S-C_6H_5
(d) X = H

The product from the reaction of 2 with 1a is, in fact, a 55:45 mixture of the maleate and fumarate esters 3a and 4a. However, a kinetic study in chloroform[2] (Table 1) using low temperature nmr to monitor the progress of the reaction showed that the addition followed second order kinetics, and that in the early stages only a single product is formed, to which we have assigned structure 3a.[3] Ratios of 3a/4a as high as 50 can be observed. The isomer 4a appears later and slowly approaches the equilibrium concentration (Figure 1). This behavior is consistent with the mechanism of eq. 1, except that 3a is subsequently isomerized to 4a (eq. 2).



(eq. 2)

N,N-Dimethyl-p-trifluoromethylbenzeneselenenamide (1b) adds to 2 approximately four times as fast as does 1a (see footnote a, Table 1). This unexpected result is accommodated by a mechanism in which Michael addition to give 5 is a reversible process, with the intramolecular selenenylation the rate determining step (eq. 1). The electron withdrawing substituent should render the nitrogen less nucleophilic, but should increase the selenenylation rate. The addition of 1b also leads to initial formation of one isomer (3b), followed by equilibration

Table 1. Kinetic Data[a,b] for Addition to Dimethyl Acetylenedicarboxylate (eq. 2).

System	Temp.	Solvent	$10^4 k$		
			k_2	k_1	k_{-1}
(a) X = SePh	-27°	$CHCl_3$	2.1	0.57[c] (0.7)[d]	0.83[c] (0.9)[d]
	-13°	"	3.2	4.3[c] (3)[d]	5.4[c] (4)[d]
	3°	"	7.8	(30)[d]	(40)[d]
	145°[e]	$PhSiMe_3$		190,000	210,000
(b) X = Se·pCF_3·C_6H_4	-13°	$CHCl_3$	19	(5.5)[d]	(7)[d]
	3°	"	24	(30)[d]	(50)[d]
	153°[e]	$PhSiMe_3$		370,000	340,000
(c) X = SPh	-27°	$CHCl_3$		0.16[c]	0.33[c]
	103°	"	0.8		
	167°[e]	$PhSiMe_3$		280,000	340,000
(d) X = H	100°	f		<0.01	0.46[e]

(a) Because of experimental difficulties in low temperature sample preparation, long term temperature control of the nmr probe, and peak area measurements, the error in most of the rate constants is between 10% and 25%.

(b) Addition reactions (1 + 2) were run with excess 1 present (0.15-0.45 M).

(c) Measured by nmr observation of pure 4 isomerizing to equilibrium mixtures of 3 and 4.

(d) The values of k_1 and k_{-1} in brackets were determined by a least squares fit of computed and observed concentrations of 3 and 4 during reaction of 1 and 2, assuming the kinetics of eq. 2 (see Figure 1).

(e) Coalescence temperature for interconversion of 3 and 4 in $PhSiMe_3$ solution, rates determined by line shape fitting.

(f) Solvent: 90% $PhSiMe_3$, 10% 1,5-diazabicyclo[4.3.0]non-5-ene.

of 3b and 4b.

We have found that N,N-dimethylbenzenesulfenamide (1c) adds to 2, but only under forcing conditions (130° higher temperature than for the selenenamides). The equilibrium mixture of geometric isomers (3c/4c = 2) is observed throughout the addition, so that it is not known whether the mechanism in the sulfur and selenium system is the same.

Dimethylamine adds to 2 as well, but at a rate rapid even at -50°. This reaction has been studied by several groups,[4] and a mechanism similar to eq. 1 involving intramolecular protonation has been postulated on the basis that the maleate adducts (3d) are formed predominantly, although not exclusively. Under appropriate conditions (CH_3OH at 0°)[4f] as much as 67% of the less stable isomer 4d (ratio of 3d/4d at equilibrium >50) is formed.

Two mechanisms for the equilibration of 3 and 4 during the addition reactions of 1a-c appeared likely: A catalytic process involving a second reversible Michael addition to 3, or a simple thermal rotation around the double bond. The latter is apparently correct as shown by analysis of the kinetics of the addition[5] and other considerations. Figure 1 shows experimental points for reaction of 1a and 2, the lines are calculated assuming the kinetics of eq. 2.

Low temperature crystallization of the mixture of 3a and 4a as well as 3c and 4c gave a single isomer (4a,c), which, when dissolved in $CHCl_3$ at low temperature, underwent first order

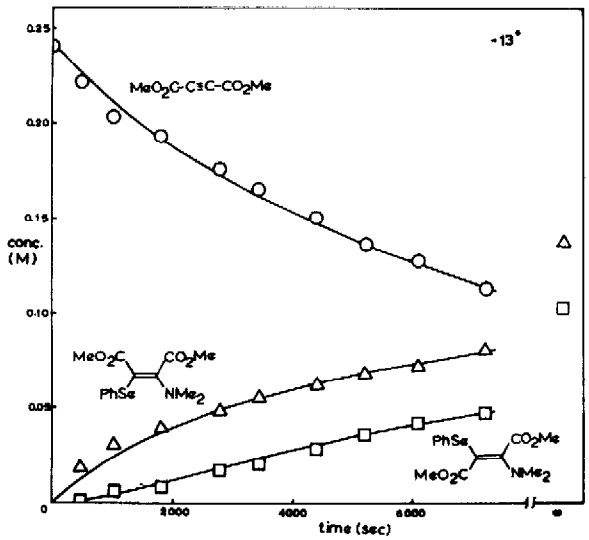


Figure 1. Addition of 1a to 2 at -13° in $CHCl_3$ ($[1a]_o = 0.40$ M; $[2]_o = 0.24$ M). The points are experimental, the solid lines were calculated using the rate constants in Table 1, and assuming the kinetics of eq. 2.

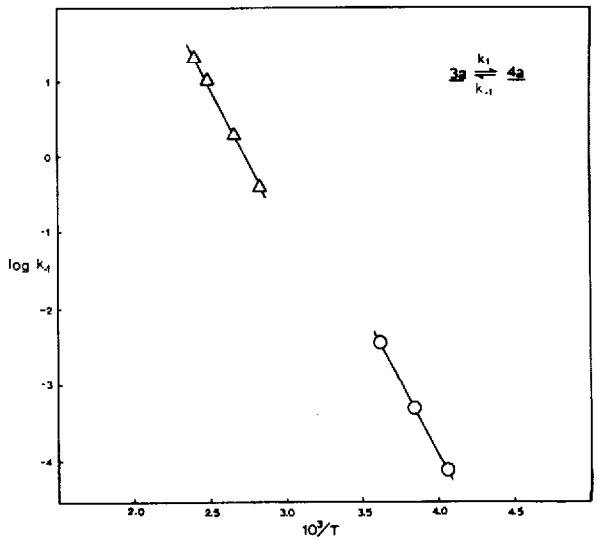


Figure 2. Temperature dependence of k_{-1} (4a→3a); ○ isomerization of pure 4a to 3a in $CHCl_3$ solution; △ nmr line shape rate measurements of 3a,4a mixture in $PhSiMe_3$ solution.[6]

isomerization back to the equilibrium mixture of 3 and 4. The values of k_1 and k_{-1} determined in this way for 4a are in agreement with the less precise values obtained from the addition kinetics (Table 1). The isomerization of 4d, obtained pure by fractional crystallization, could similarly be studied, except that isomerization is strongly acid catalyzed. Relatively reproducible rates could only be obtained in the presence of 0.1-0.3 equivalents of 1,5-diazabicyclo[4.3.0]non-5-ene (DBN). Under these conditions base catalysis becomes possible; the rate measured is thus only a maximum for the thermal isomerization.

High temperature nmr spectra of equilibrium mixtures of 3a and 4a, as well as 3b-4b and 3c-4c gave line broadening and coalescence of the four OCH_3 resonances to two peaks. Line shape analysis gave values for k_1 and k_{-1} reasonably compatible with data obtained above. Figure 2 compares the temperature dependence of k_{-1} (4a → 3a) measured by low temperature isomerization and high temperature line broadening techniques.[6]

The free energies of activation for double bond rotation (k_{-1}) in 4a, 4b, 4c, and 4d are: $\Delta G^{\ddagger}$ kcal/mole (°C): 18.9 (-27°), 18.9 (-13°), 19.4 (-27°), >29.4 (100°). The approximate relative rates for 4a, 4b and 4c are 1:1.3:0.4, with 4d 10^{-7} to 10^{-10} depending on the entropy of activation.[6] The facile interconversions of these maleate and fumarate esters do not seem to have the properties expected for a dipolar mechanism. While sulfur and selenium will both stabilize the negative end of a dipolar transition state, the data available suggest that PhS should stabilize a carbanion more than PhSe,[7] contrary to what is observed. Similarly, the failure of the CF_3 substituent in 4b to significantly accelerate isomerization when compared with 4a is inconsistent with the development of substantial negative charge in the transition state. This evidence would

seem to favor a nonpolar (diradical) electronic structure for the transition state of bond rotation.

Most previous examples of compounds which undergo facile bond rotation ($\Delta G^{\ddagger}$ <25 kcal/mole) have had at least one end of the double bond substituted with two strongly electron donating or attracting groups, while the other end had groups of opposite polarity.[8] This situation is not present in compounds 3 and 4, where each end of the double bond bears one electron attracting group, and one potentially electron donating group. The occurrence of a nonpolar mechanism in 3 and 4 is therefore not surprising.

Acknowledgement

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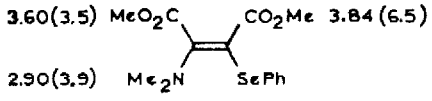
REFERENCES AND FOOTNOTES

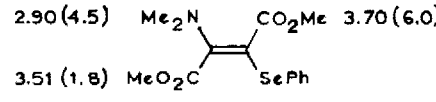
1. H. J. Reich and J. M. Renga, J. Org. Chem., 40, 3313 (1975).

2. In benzene, CCl_4 and CH_2Cl_2 addition did not compete effectively with isomerization (3a → 4a).

3. The nmr chemical shifts, δ $CDCl_3$ and Eu(fod)$_3$ shifts (slope of δ vs. equiv. Eu plots) of 3a and 4a are given below. The europium shifts are best rationalized on the basis that 3 is the



3a



4a

Z isomer and that complexation of Eu occurs primarily at the carbonyl conjugated with dimethylamino. Similar chemical shifts and Eu(fod)$_3$ shifts are found for 3b,c,d and 4b,c,d.

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5. The kinetic data of Table 1 are not sufficiently accurate for determination of meaningful activation parameters, but the temperature dependence of k_2 for 1a gives $\Delta H^{\ddagger} \approx 5.4$ kcal/mol, $\Delta S^{\ddagger} \approx -53$ eu, whereas k_1 gives a much less negative $\Delta S^{\ddagger}$.[6]

6. For 3a/4a the low temperature measurements of k_{-1} in $CHCl_3$ (Figure 2) give $\Delta H^{\ddagger} = 16.9 \pm 2$ kcal/mole, $\Delta S^{\ddagger} = -8 \pm 5$ eu, whereas the high temperature coalescence data in $PhSiMe_3$ give $\Delta H^{\ddagger} = 17.4 \pm 2$ kcal/mole, $\Delta S^{\ddagger} = -12 \pm 5$ eu. It appears that these are within experimental error of each other, considering possible solvent effects (4a was not sufficiently soluble in $PhSiMe_3$ for measurement k_{-1}; in 10% $CHCl_3$-90% $PhSiMe_3$ the rate is indistinguishable from that in $CHCl_3$).

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