

## CYCLOADDITIONS OF N,N'-DICYCLOHEXYLCARBODIIMIDE TO 2-PHENYLETHENYL ISOTHIOCYANATES

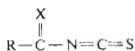
Ol'ga HRITZOVÁ and Ladislav KNEŽO

Department of Organic Chemistry and Biochemistry,  
P. J. Šafárik University, 041 67 Košice

Received July 8th, 1982

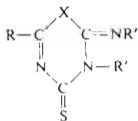
2-Phenylethenyl- and 2-(4-nitrophenyl)ethenyl isothiocyanates undergo a 2 + 2 cycloaddition with N,N'-dicyclohexylcarbodiimide to form 1,3-thiazetidine derivatives; this reaction takes place at the C=S bond of the isothiocyanate group. The olefinic C=C bond was not involved,

Isothiocyanates can be the starting material for cycloaddition reactions leading to a plethora of heterocyclic compounds<sup>1-3</sup>. Whereas the heterocumulene grouping in the isothiocyanates —N=C=S can enter the cycloaddition reactions either through the C=S or C=N bond, isothiocyanates having the —NCS group in conjugation with another double bond C=X (*cf. I*) can react with the 2π electron system in the already mentioned reactions in four various ways. The cycloadditions can theoretically occur at C=X, C=N, or C=S bond, the 4 + 2 cycloaddition at X=C—N=C.

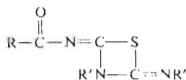


*I*, X = S, R = R<sub>2</sub>N

*II*, X = O



*III*

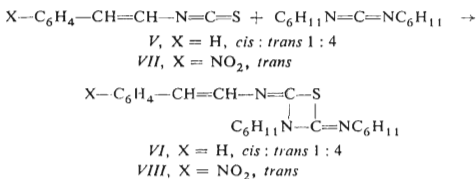


*IV*

Cycloadditions are, however, characteristic of selectivity, *i.e.* in contrast to the possibilities just mentioned, the formation of a sole cycloadduct is very probable. Thus, *e.g.* in the reaction of —NCS group in conjugation with a C=S bond with N,N'-dicyclohexylcarbodiimide the 4 + 2 cycloaddition is periselective and consequently, the product is a derivative of thiazetidine *III* (X = S, *ref.*<sup>4</sup>). Acyl isothiocyanates *II* on the other hand, react ambiguously: with aliphatic carbodiimides either 2 + 2 cycloadducts *IV* (*ref.*<sup>5,6</sup>) or 4 + 2 cycloadducts *III* (X = O, *ref.*<sup>6</sup>) were formed depending on condition. It was of interest, which pericyclic process shall be involved

in the cycloaddition of aliphatic carbodiimide to isothiocyanate with an —NCS group in conjugation with the C=C bond.

N,N'-Dicyclohexylcarbodiimide was, therefore, reacted with 2-phenylethenyl isothiocyanate<sup>7</sup> and the cycloaddition under the same conditions was found to proceed as with phenyl isothiocyanate<sup>8</sup>. Thin-layer chromatography of the reaction mixture showed that the starting 2-phenylethenyl isothiocyanate (V), which was a 1 : 4 mixture of *cis* and *trans* isomers, afforded two reaction products only. Chromatography through a silica gel column separated these products in a 64% yield; as evidenced, they were the *cis* and *trans* isomers of 2-phenylethenylimino-3-cyclohexyl-4-cyclohexylimino-1,3-thiazetidene (VI).



#### SCHEME I

The structure of both cycloadducts isolated, differing in the configuration at the C=C bond was inferred from the IR, <sup>1</sup>H NMR and mass spectral data. The *trans* isomer was isolated as a crystalline product of m.p. 71–73°C. The mass spectrum of this compound revealed the nominal molecular weight at *m/z* 367 and other fragment ions at *m/z* 161, 206 corresponding to molecular weights of starting compounds after a retrocycloaddition reaction. The IR spectra displayed an absorption band at 1 657 cm<sup>-1</sup>, indicative of an exocyclic C=N bond<sup>6</sup> and another one at 938 cm<sup>-1</sup> characteristic of bending vibrations of the C—H bond in *trans* derivatives. The *trans* configuration at the C=C bond was also seen in the <sup>1</sup>H NMR spectrum showing, in addition to aromatic and cyclohexyl protons, two doublets at δ 6.65 ppm (*J* = 14.0 Hz). The *cis* isomer, oily in nature decomposed when attempted to distil into the mixture of starting material. The mass spectrum of the not distilled product showed a peak of molecular radical ion at *m/z* 367 and the IR spectrum an absorption band at 1 650 cm<sup>-1</sup> associated with the exocyclic C=N bond. The *cis* configuration at the double bond was confirmed by the <sup>1</sup>H NMR spectrum displaying two doublets at δ 6.02 ppm (*J* = 8.0 Hz).

As known, the electron withdrawing substituent alters the electron distribution and frontier orbital energies of the molecule entering the cycloaddition reaction<sup>9</sup>, what can be manifested even in the alteration of the reaction course. To verify, whether the presence of a nitro group influences the periselectivity of the reaction

under investigation, N,N'-dicyclohexylcarbodiimide was reacted with *trans*-2-(4-nitrophenyl)ethenyl isothiocyanate<sup>10</sup> (VII). The product, a derivative of 1,3-thiazetidine VIII was the only substance of this reaction thus evidencing the cycloaddition at C=S bond. Its structure was corroborated similarly as with the preceding products, *i.e.* by IR, <sup>1</sup>H NMR and mass spectral data. The IR spectrum displayed an absorption band at 1 655 cm<sup>-1</sup>, characteristic of an exocyclic C=N bond, and another one at 938 cm<sup>-1</sup> belonging to bending C—H vibrations in the *trans* derivative. The <sup>1</sup>H NMR spectrum revealed two doublets at  $\delta$  6.76 ppm ( $J = 14.0$  Hz). Mass spectrum of the cycloadduct showed the peak of molecular radical ion at  $m/z$  412 and further peaks of ions at  $m/z$  206 and 141 coming from the cleavage of the 1,3-thiazetidine ring.

These results allowed us to conclude that the heterodiene —C=C—N=C=S system reacts with N,N'-dicyclohexylcarbodiimide selectively through its C=S bond to afford the 2 + 2 cycloadduct. The alternative 4 + 2 cycloaddition, also involving the olefinic C=C bond, was not manifested in the reaction of 2-phenylethenyl isothiocyanate and 2-(4-nitrophenyl)ethenyl isothiocyanate.

## EXPERIMENTAL

The IR spectra were measured in the 800—3 600 cm<sup>-1</sup> range with a Specord 75 IR instrument in NaCl cells at a 0.04—0.06 mol l<sup>-1</sup> concentration in chloroform. The <sup>1</sup>H NMR spectra were recorded with a Tesla BS 487 A spectrometer, operating at 80 MHz, in deuteriochloroform containing tetramethylsilane as an internal reference. The mass spectra were taken with an MS 902 S (AEI, Manchester) instrument at an electron ionization energy 70 eV, and 80 and 110°C ionization chamber temperatures.

2-Phenylethenyl isothiocyanate (V), b.p. 101—102°C/130 Pa was prepared according to<sup>7</sup>, 2-(4-nitrophenyl)ethenyl isothiocyanate (VII), m.p. 160—162°C according to<sup>10</sup>; m.p. of N,N'-dicyclohexylcarbodiimide was 33—35°C.

### Reaction of 2-Phenylethenyl Isothiocyanate (V) with N,N'-Dicyclohexylcarbodiimide

The mixture of V (0.48 g, 3 mmol) and N,N'-dicyclohexylcarbodiimide (12.36 g, 60 mmol, a 20-fold excess) in CCl<sub>4</sub> (50 ml) was stirred at 50°C for 21 h and at room temperature for additional 24 h. Thin-layer chromatography showed the presence of the unreacted N,N'-dicyclohexylcarbodiimide and two more products. The solvent was distilled off under diminished pressure and the residue was twice chromatographed on a silica gel column (eluent benzene—light petroleum 1 : 15).

*trans*-2-Phenylethenylimino-3-cyclohexyl-4-cyclohexylimino-1,3-thiazetidine (VI), m.p. 71—73° (methanol); yield 0.55 g, (51%). For C<sub>22</sub>H<sub>29</sub>N<sub>3</sub>S (367.5) calculated: 71.89% C, 7.95% H, 11.42% N; found: 71.54% C, 7.85% H, 11.51% N. IR spectrum:  $\nu(\text{C}=\text{N})_{\text{exo}}$  1 675 cm<sup>-1</sup>,  $\nu(\text{C}=\text{C})$  1 615, 1 590 cm<sup>-1</sup>,  $\nu(\text{C}-\text{H trans})$  938 cm<sup>-1</sup>. <sup>1</sup>H NMR spectrum ( $\delta$ ): 6.65 (dd,  $J_{\text{AB}} = 14.0$  Hz, —CH=CH— *trans*). Mass spectrum  $m/z$  (rel. intensity, %): 367 (1.3), 226 (4.8), 206 (14.8), 161 (100), 117 (10), 109 (12.7), 103 (27.6), 97 (17.2), 83 (62.1), 77 (44.8).

*cis*-2-Phenylethenylimino-3-cyclohexyl-4-cyclohexylimino-1,3-thiazetidine, oil, yield 0.14 g (13%) IR spectrum:  $\nu(\text{C}=\text{N})_{\text{exo}}$  1 650 cm<sup>-1</sup>,  $\nu(\text{C}=\text{C})$  1 610, 1 590 cm<sup>-1</sup>. <sup>1</sup>H NMR spectrum ( $\delta$ ): 6.02 (dd,  $J_{\text{AB}} = 8.0$  Hz, —CH=CH— *cis*).

*trans*-2-(4-Nitrophenyl)ethenylimino-3-cyclohexyl-4-cyclohexylimino-1,3-thiazetidine (VIII)

The mixture of VII (0.55 g, 24 mmol) and N,N'-dicyclohexylcarbodiimide (9.8 g, 48 mmol) in CCl<sub>4</sub> (50 ml) was stirred at 50°C for 9 h in a nitrogen atmosphere and at an ambient temperature for additional 48 h. The solvent was distilled off *in vacuo* and the residue chromatographed on a silica gel column (eluent acetone-light petroleum 1 : 8). The yield of VIII 0.57 g (52%), m.p. 125–127°C (acetone). For C<sub>22</sub>H<sub>28</sub>N<sub>4</sub>O<sub>2</sub>S (412.5) calculated: 64.06% C, 6.84% H, 13.57% N; found: 64.51% C, 6.95% H, 13.32% N. IR spectrum:  $\nu(\text{C}=\text{N})_{\text{ext}}$  1 655 cm<sup>-1</sup>,  $\nu(\text{C}=\text{C})$  1 615, 1 577 cm<sup>-1</sup>,  $\nu(\text{NO}_2)$  1 510, 1 335 cm<sup>-1</sup>,  $\nu(\text{C}-\text{H trans})$  938 cm<sup>-1</sup>. <sup>1</sup>H NMR spectrum ( $\delta$ ): 6.76 (dd,  $J_{\text{AB}} = 14.0$  Hz —CH=CH— *trans*). Mass spectrum  $m/z$  (rel. intensity, %): 412 (1.5), 206 (23.8), 149 (77.7), 141 (27.7), 135 (9.4), 123 (15.5), 109 (15.0), 97 (26.6), 83 (100).

The authors are indebted to Dr J. Leško, Laboratory for Mass Spectrometry, Slovak Institute of Technology, Bratislava, for mass spectra.

## REFERENCES

1. Ulrich H. in the book: *Cycloaddition Reactions of Heterocumulenes*, (A. T. Blomquist, Ed.), Academic Press, New York 1967.
2. van Loock E.: *Ind. Chim. Belge* 39, 661 (1974).
3. Drobnica L., Kristian P., Augustin J. in the book: *The Chemistry of the Cyanates and Their Thio Derivatives* (S. Patai, Ed.), Part 2, p. 1003. Wiley, London 1977.
4. Goerdeler J., Lüdke H.: *Chem. Ber.* 103, 3393 (1970).
5. Ulrich H., Tucker B., Sayigh A. A. R.: *J. Amer. Chem. Soc.* 94, 3484 (1972).
6. Hritzová O., Kristian P.: *This Journal* 43, 3258 (1978).
7. Kniežo L., Kristian P.: *Chem. Zvesti* 28, 848 (1974).
8. Dondoni A., Battaglia A.: *J. Chem. Soc. Perkin Trans. 2*, 1975, 1475.
9. Houk K. N.: *Accounts Chem. Res.* 8, 361 (1975).
10. Kniežo L., Kristian P., Velebný S.: *This Journal* 43, 1917 (1978).

Translated by Z. Votický.