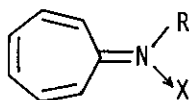


THE FORMATION OF [3+2] CYCLOADDUCTS AND THEIR CONVERSIONS: REACTIONS OF
N-CYCLOHEPTATRIENYLIDENEAMINE OXIDE WITH ISOCYANATES AND ISOTHIOCYANATES

Shoji Kajigaeshi*, Shingo Matsuoka, Shuji Kanemasa**, and Michihiko Noguchi
Department of Industrial Chemistry, Faculty of Engineering,
Yamaguchi University, Tokiwadai, Ube 755, Japan

Abstract — The spiro [3+2] cycloadducts from N-cycloheptatrienylidene-methylamine oxide with alkyl isocyanates were isolated and characterized. The reaction of N-oxide with isothiocyanates afforded cyclohepta[d]imidazole, cyclohepta[d]thiazole, and/or 2-methylaminotropothione, which were brought through the similar [3+2] cycloadducts.

Recently, we have reported that 8-azaheptafulvenes (1) behave exclusively an 8 π electron system to afford [8+2] cycloadducts in the reaction with heterocumulenes¹. In a continuation of our studies, the next attention has been paid for the reaction of N-cycloheptatrienylideneamine oxide



1: X = —

2: X = O

3: X = O ; R = Me

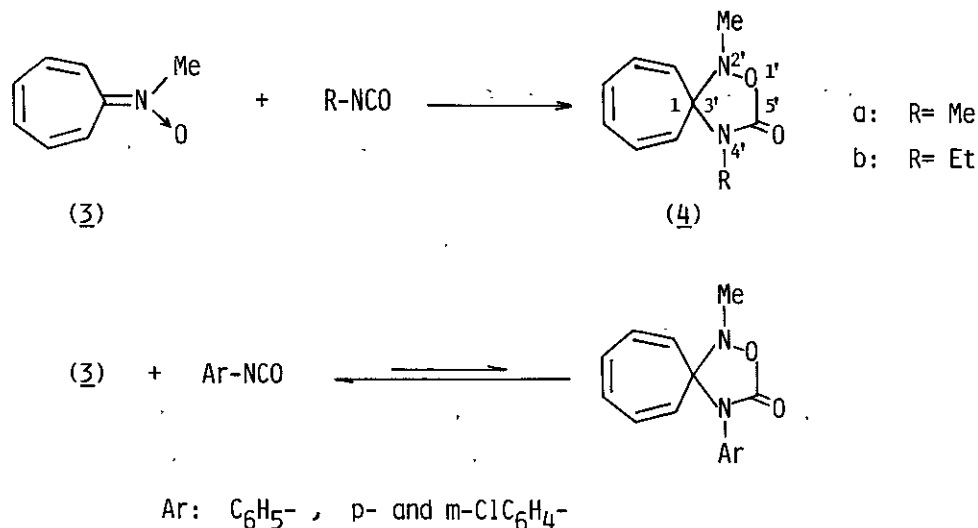
(2), because 2 is regarded as the N-oxide of 8-azaheptafulvene (1). Now, only two examples concerning the reaction of 2 were reported by Houk and his co-workers². Therein, the cycloaddition reaction of N-cycloheptatrienylidenemethylamine oxide (3) with the electron deficient dipolarophiles occurred on the nitrone (4 π) or the cycloheptatrienylidene moiety (4 and 6 π) in 3.

In this communication we wish to describe a successful isolation of the spiro [3+2] cycloadducts in the reaction of 3 with alkyl isocyanates and the interesting reactions via the decomposition of the spiro [3+2] cycloadducts in that with isothiocyanates.

When an equimolar (3 mM) mixture of N-oxide (3) and methyl isocyanate in dry chloroform (10 ml) was stirred at room temperature for 5 h and concentrated in vacuo to give the residue, which was purified with chromatography on silica gel, a spiro (cycloheptatriene)-1,3'-(2',4'-dimethyl-5'-oxo-1',2',4'-oxadiazolidine) (4a), mp 68.5-69.5 °C, was isolated in 59% yield as colorless prisms.

** Present address: Research Institute of Industrial Science, Kyushu University, Kasuga, Kasuga-shi, Fukuoka 816, Japan.

Scheme



The structural elucidation of 4a was accomplished on the basis of the spectral data³; especially, in ¹H-nmr spectrum a simplified signal pattern of olefinic protons indicated the symmetrical structure of 4a and, furthermore, in ¹³C-nmr spectrum a spiro sp³-carbon signal at 83.6 ppm was characterized by off-resonance technique. Similarly, the reaction of 3 with ethyl isocyanate afforded a spiro [3+2] cycloadduct (4b)⁴ in 36% yield.

Previously, in the reaction of N-oxide (3) with phenyl vinyl sulfone Houk et al. postulated the [3+2] cycloadduct as an intermediate, but failed to isolate due to its unstability². Thus, the spiro [3+2] cycloadduct from N-oxide (3) and 2 pai dipolarophile was herein isolated and characterized for the first time.

However, the reactions with aryl isocyanates in the similar conditions afforded no any adducts, but the starting material, N-oxide (3), was recovered almost quantitatively in every case.

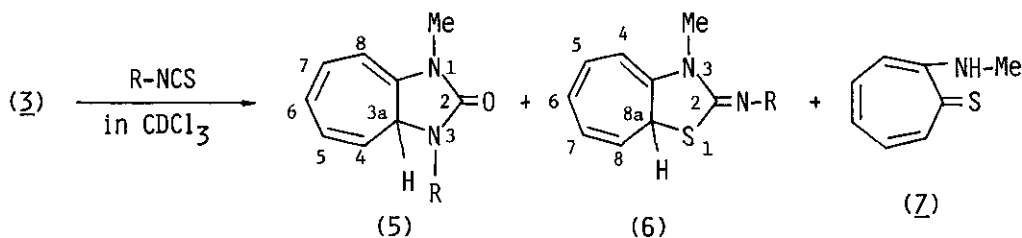
Now, the ¹H-nmr spectra of the reaction mixtures showed the formation of the spiro [3+2] cycloadducts⁵ just after the mixing of the two reactants, but the intensity of the signals assigned to the [3+2] cycloadduct had diminished gradually and finally the signals disappeared after about 2 h at 50 °C. Some efforts in order to isolate these spiro cycloadducts were made without success.

— This means the existence of a rapid cycloreversion which provides the starting materials from the [3+2] cycloadduct. These results were in agreement with the thermal mobility of the spiro [3+2] cycloadducts (4)⁶.

The reactions of 3 with isothiocyanates were further investigated. It turned out that they were more complicated than those with isocyanates. For example, the heating of 3 with phenyl isothiocyanate in chloroform gave two main products, 5a and 6a, in 20 and 21% yields, respectively, together with sulfur and a trace of 2-methylaminotropothione (7)⁷. Now, 5a and 6a were identi-

fied as a 1,3-dimethyl-2-oxo-2,3-dihydro-3aH-cyclohepta[d]imidazole^{1a} and a 3-methyl-2-phenylimino-2,3-dihydro-8aH-cyclohepta[d]thiazole^{1a}, cycloadducts formed by treating 8-methyl-8-azaheptafulvene with phenyl isocyanate and phenyl isothiocyanate respectively, on the basis of the consistency with the melting points and spectral data of the authentic samples. Similarly, the reactions of 3 with p-cyanophenyl-, tosyl-, and methyl isothiocyanate provided 5, 6, and/or 7. These results are summarized in Table I and Table II.

Table I Reactions of N-Oxide (3) with Isothiocyanates



R	Reaction Condition (h)	Yield (%)		
		<u>5</u>	<u>6</u>	<u>7</u>
a C ₆ H ₆	reflux, 76	20	21	trace
b p-CN-C ₆ H ₄	reflux, 3.5	38	5	trace
c Ts	r.t., 1	24	0	33
d Me	reflux, 80	0	16	trace

Table II The Melting Points and Spectral Data of Cyclohepta[d]imidazoles (5) and Cyclohepta[d]-thiazoles (6)

Compds	mp (°C)	¹ H-nmr (CDCl ₃) δ							ir (KBr) ₋₁ cm ⁻¹		M ⁺ (m/e)
		3a-H ^{br}	4-H ^{dd}	5-H ^m	6-H ^m	7-H ^{dd}	8-H ^d	-Me ^s	C=O	C=C	
<u>5a</u> a)	93-95 b)	4.48	5.04	6.3 - 6.7	6.85	5.66	3.20		1720	1630	238
<u>5b</u>	187-189	4.24	4.82	6.1 - 6.6	6.69	5.50	3.06		1740	1635	263
<u>5c</u>	188-189 b)	4.61	5.3	6.1 ———	6.8	5.55	2.47 3.00		1740	1645	317
		8a-H ^{br}	8-H ^{dd}	7-H ^m	6-H ^m	5-H ^{dd}	4-H ^d	-Me ^s	C=C	C=N	
<u>6a</u> a)	68-70 b)	3.81	5.05	6.04	6.14	6.49	5.42	3.23	1635	1585	254
<u>6b</u>	156	3.91	5.13	6.0 - 6.4	6.59	5.58	3.26		1640	1590	279
<u>6d</u>	oil	3.87	5.09	6.0 - 6.3	6.60	5.43	3.11 3.14		1665	1590	192

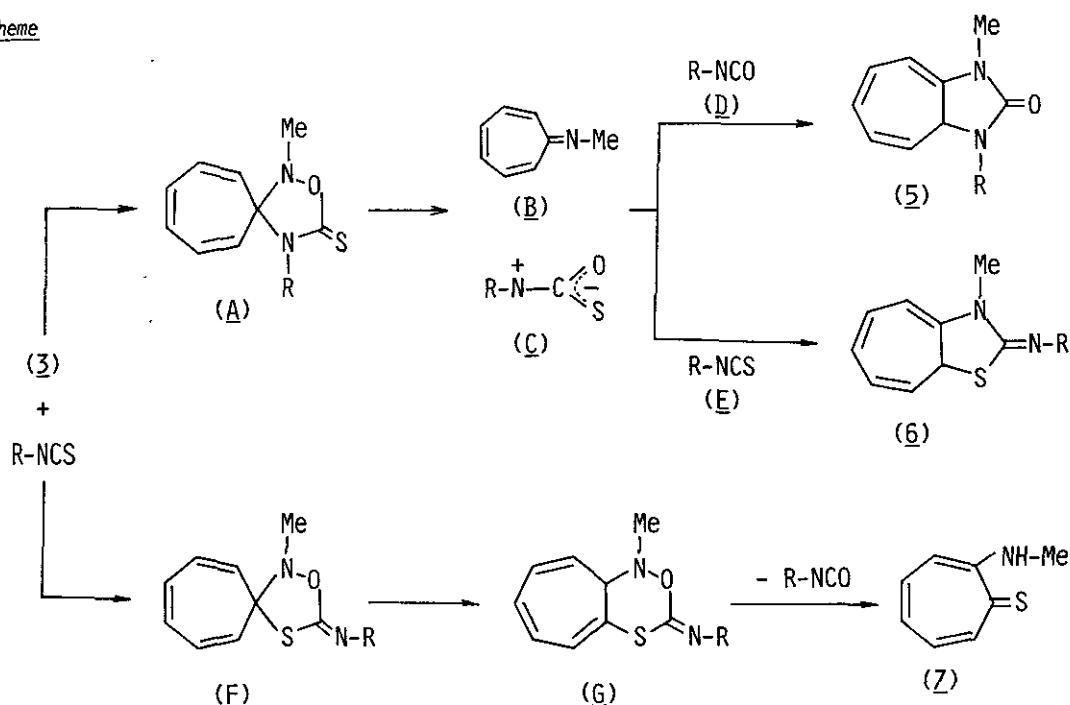
a) Known compounds. See ref. 1a.

b) Melted with decomposition.

To explain the loss of the sulfur or oxygen atom from the (1:1) adduct of N-oxide (3) and isothiocyanate, we suggest the following reaction pathway, which is made of three steps, i.e., i) the decomposition of the spiro [3+2] cycloadduct (A) to an 8-azaheptafulvene (B) and a betaine (C); ii) the subsequent generation of an isocyanate (D) or an isothiocyanate (E) by the loss of sulfur or oxygen atom from C; iii) followed by the cycloaddition reaction of B with D or E.

On the other hand, the reaction pathway giving Z is not secure, however one possible explanation is to postulate the intermediacy of another type of spiro [3+2] cycloadduct (F) which is resultant from the addition of nitron moiety in 3 to the C=S bond in isothiocyanate⁹. The cycloadduct (F) is converted into a cyclohepta[d]-1,3,6-oxazine (G), which proceeds a cycloreversion to afford Z and isocyanate (D).

Scheme



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 c) T. Iwasaki, S. Kajigaeshi, and S. Kanemasa, *Bull. Chem. Soc. Jpn.*, 1978, 51, 229.
2. D. Mukhejee, L. N. Domeismith, and K. N. Houk, *J. Am. Chem. Soc.*, 1978, 100, 1954.
3. 4a: Ir(KBr) 1740, 1410, 1360 cm^{-1} ; ^1H -nmr(CDCl_3) δ 2.61(3H, s, Me), 2.88(3H, s, Me), 5.72(2H, br d, 2- and 7-H), 6.6-6.9(4H, m, olefinic H); ^{13}C -nmr(CDCl_3) δ 27.5(q), 39.5(q), 83.6(s).

- 123.3(d), 130.2(d), 156.3(s); mass spectrum m/e 192(M^+), 147($M^+ - MeNO$).
4. 4b: Colorless prisms; mp 56 °C; $ir(KBr)$ 1760, 1375 cm^{-1} ; 1H -nmr($CDCl_3$) δ 1.24(3H, t, $-CH_2CH_3$), 2.48(3H, s, Me), 3.27(2H, q, $-CH_2CH_3$), 5.52(2H, d, 2- and 7-H), 6.4-6.6(4H, m, olefinic H); mass spectrum m/e 206(M^+), 161($M^+ - EtNO$).
5. In the 1H -nmr spectrum of the mixture of 3 and phenyl isocyanate in $CDCl_3$, the observed new signals were assigned as below; δ 2.44(3H, s, Me) and 5.72(2H, br d, 2- and 7-H) for the spiro cycloadduct similar to 4.
6. When 4a was heated in toluene at reflux for 1 h and worked up usually, N-oxide (3) was regenerated quantitatively.
7. 7: Yellow prisms; mp 68-69.5 °C (lit.⁸ mp 67-68.5 °C); $ir(KBr)$ 1590, 1520, 1030 cm^{-1} ; 1H -nmr($CDCl_3$) δ 3.16(3H, d, Me, $J = 5$ Hz), 6.72(1H, d), 6.9-7.5(3H, m), 8.66(1H, m), 9.15(1H, br s, NH); mass spectrum m/e 151(M^+).
8. W. R. Brasen and R. E. Benson, *J. Am. Chem. Soc.*, 1961, 83, 3135.
9. The addition of nitrile imine occurred onto the C=N and C=S bonds in isothiocyanate¹⁰.
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