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

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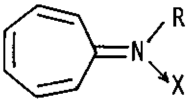
Abstract ——— The spiro [3+2] cycloadducts from N-cycloheptatrienylidenemethylamine oxide with alkyl isocyanates were isolated and characterized. The reaction of N-oxide with isothiocyanates afforded cyclohepta[d]imidazole, cyclohepta[d]thiazole, and/or 2-methylaminotropothione, which were brought through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

Recently, we have reported that 8-azaheptafulvenes (1) behave exclussively an 8 pai electron system to afford [8+2] cycloadducts in the reaction with heterocumulenes[1]. In a continuation of our studies, the next attention has been paid for the reaction of N-cycloheptatrienylideneamine oxide (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-wokers[2]. Therein, the cycloaddition reaction of N-cycloheptatrienylidenemethylamine oxide (3) with the electron deficient dipolarophiles occurred on the nitrone (4 pai) or the cycloheptatrienylidene moiety (4 and 6 pai) in 3.



1: X= —

2: X= O

3: X= O ; R= Me

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.

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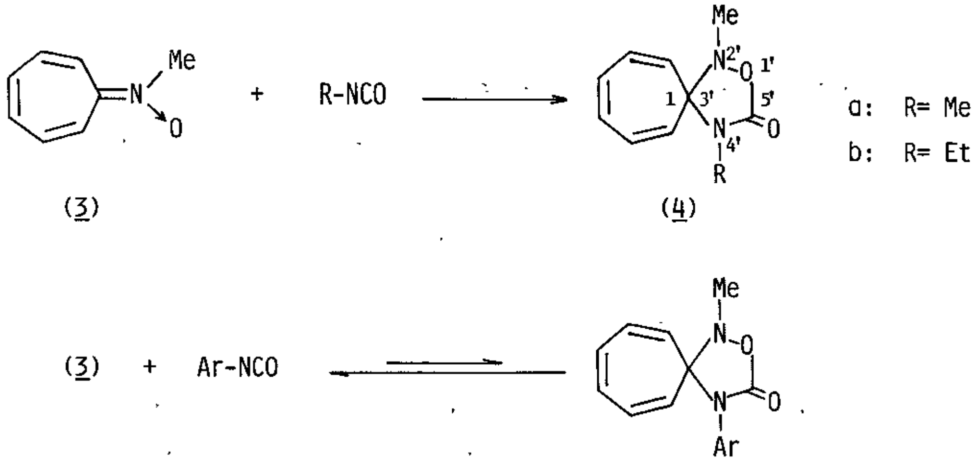
Scheme



Ar: C_6H_5- , p- and m-ClC_6H_4-

The structural elucidation of 4a was accomplished on the basis of the spectral data^{3}; especially, in ^{1}H-nmr spectrum a simplified signal pattern of olefinic protons indicated the symmetrical structure of 4a and, furthermore, in ^{13}C-nmr spectrum a spiro sp^{3}-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 unstability^{2}. Thus, the spiro [3+2] cycloadduct from N-oxide (3) and 2 pai dipolarophile was herein isolated and characterized for the first time.

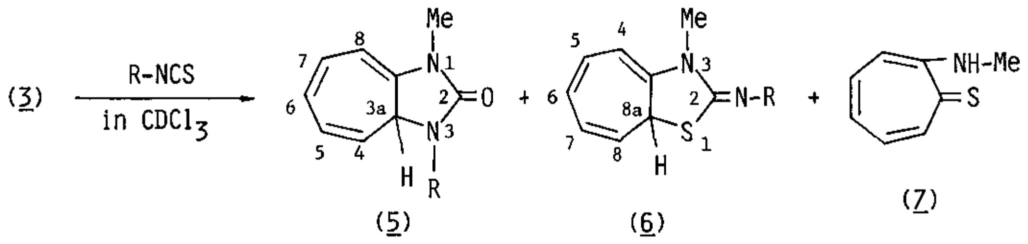
However, the reactions with aryl isocyanates in the similar conditions afforded no any adducts, but the starting material, N-oxide (3), was recovered almost quantitatively in every case.

Now, the ^{1}H-nmr spectra of the reaction mixtures showed the formation of the spiro [3+2] cycloadducts^{5} 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 oder 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 identified 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 summerized in Table I and Table II.

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



	R	Reaction Condition (h)		Yield (%) 5	6	7
a	C_6H_6	reflux,	76	20	21	trace
b	p-CN-C_6H_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)

		^{1}H-nmr ($CDCl_3$) δ							ir (KBr) cm^{-1}		
Compds	mp (°C)	3a-H^{br}	4-H^{dd}	5-H^{m}	6-H^{m}	7-H^{dd}	8-H^{d}	-Me^{s}	C=O	C=C	M$^+$(m/e)
5a a)	93-95 b)	4.48	5.04	6.3 — 6.7		6.85	5.66	3.20	1720	1630	238
5b	187-189	4.24	4.82	6.1 — 6.6		6.69	5.50	3.06	1740	1635	263
5c	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	
6a a)	68-70 b)	3.81	5.05	6.04	6.14	6.49	5.42	3.23	1635	1585	254
6b	156	3.91	5.13	6.0 — 6.4		6.59	5.58	3.26	1640	1590	279
6d	oil	3.87	5.09	6.0 — 6.3		6.60	5.43	3.11 3.14	1665	1590	192

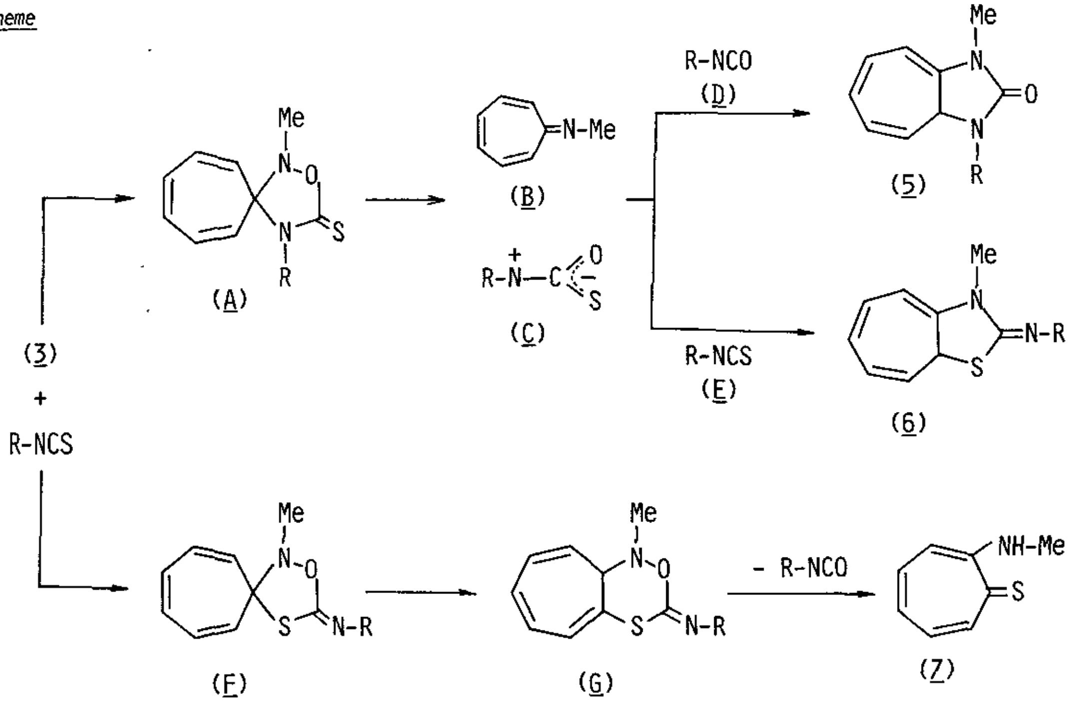
a) Known compounds. See ref. 1a.

b) Melted with decomposition.

To explain the loss of the sulfur or oxgen 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 oxgen atom from C; iii) followed by the cycloaddition reaction of B with D or C.

On the other hand, the reaction pathway giving 7 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 nitrone moiety in 3 to the C=S bond in isothiocyanate[9]. The cycloadduct (F) is converted into a cyclohepta[d]-1,3,6-oxazine (G), which proceeds a cycloreversion to afford 7 and isocyanate (D).

Scheme



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   b) K. Yamamoto, S. Kajigaeshi, and S. Kanemasa, Chem. Lett., 1977, 91.
   c) T. Iwasaki, S.Kajigaeshi, and S. Kanemasa, Bull. Chem. Soc. Jpn., 1978, 51, 229.
2. D. Mukhejee, L. N. Domelsmith, and K. N. Houk, J. Am. Chem. Soc., 1978, 100, 1954.
3. 4a: Ir(KBr) 1740, 1410, 1360 cm^{-1}; ^{1}H-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}; ^{1}H-nmr($CDCl_3$) δ 1.24(3H, t, $-CH_2C\underline{H}_3$), 2.48(3H, s, Me), 3.27(2H, q, $-C\underline{H}_2CH_3$), 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 ^{1}H-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}; ^{1}H-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^+).

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9. The addition of nitrile imine occurred onto the C=N and C=S bonds in isothiocyanate[10].

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