Compound (X), IR spectrum (ν, cm^{-1}): 1094 (C–O), 1754 (C=O), 2140 (C≡C), 3047 (OH); PMR spectrum: 4.8 m (OCH_2), 4.25 s (CH_2CO), 3.68 s (OH), 2.64 t (≡CH, ^4J = 2.5); mass spectrum, m/z (I, %): 113(10) $[M - H]^+$, 97(10) $[M - OH]^+$, 39(90) $[C_3H_3]^+$, 28(100).

Compound (XI), IR spectrum (ν, cm^{-1}): 1756 (C=O), 2133 (C≡C); PMR spectrum: 4.78 m (OCH_2), 4.33 s (CH_2CO), 2.52 t (≡CH, ^4J = 2.5); mass spectrum, m/z (I, %): 154(5) $[M - OCH_2C{\equiv}CH{-}H]^+$, 127(10) $[M - COOCH_2C{\equiv}CH]^+$, 113(10) $[M - CH_2COOCH_2C{\equiv}CH]^+$, 97(5) $[M - OCH_2COOCH_2 \cdot C{\equiv}CH]^+$, 39(100) $[C_3H_3]^+$.

LITERATURE CITED

1. E. A. Shapiro, T. N. Romanova, I. E. Dolgii, and O. M. Nefedov, Izv. Akad. Nauk SSSR, Ser. Khim., No. 11, 2501 (1987).
2. H. Hirai and M. Matsui, Agric. Biol. Chem., 40, No. 1, 169 (1976).
3. J. A. MacLaren, Aust. J. Chem., 25, No. 6, 1293 (1972).
4. A. R. Manning, J. Chem. Soc. (A), No. 3, 651 (1968).
5. E. A. Shapiro, G. V. Lun'kova, I. E. Dolgii, and O. M. Nefedov, Izv. Akad. Nauk SSSR, Ser. Khim., No. 11, 2529 (1984).
6. R. Paulissen, H. Reimlinger, E. Hayes, et al., Tetrahedron Lett., No. 24, 2233 (1973).
7. M. P. Doyle, J. H. Griffin, M. S. Chin, et al., J. Org. Chem., 49, No. 11, 1917 (1984).
8. M. Vidal, M. Vincens, and P. Arnaud, Bull. Soc. Chim. Fr., No. 2, 657 (1972).
9. D. A. Harbourne and F. G. A. Stone, J. Chem. Soc. (A), No. 8, 1765 (1968).
10. O. Gambino, G. A. Vaglio, R. P. Ferrario, et al., Org. Mass Spectrom., 6, No. 7, 723 (1972).

REACTION OF DIAZOALKANES WITH UNSATURATED COMPOUNDS.

10.* 1,3-DIPOLAR CYCLOADDITION OF DIAZOCYCLOPROPANE TO STRAINED CYCLOALKENES

Yu. V. Tomilov, E. V. Shulishov, and O. M. Nefedov

UDC 542.91:547.512+547.235.41

The reaction of diazocyclopropane, generated in situ by alkaline hydrolysis of N-nitroso-N-cyclopropylurea at −20° to −40°C, with the double bond of norbornene hydrocarbons or 3,3-dimethylcyclopropene is a 1,3-dipolar cycloaddition and affords 45-70% yields of thermally stable 1-pyrazolines possessing a spiro-joined cyclopropane fragment. Methylenecyclopropane under the same conditions is a less effective and selective interceptor of diazocyclopropane, forming in ~ 10% yields not only isomeric 1-pyrazolines but the corresponding product of cyclopropylization, dispiro[2.0.2.1]heptane.

Diazocyclopropane (DCP) is not obtained as an individual compound. However, during attempts to generate it, as, for example, by alkaline hydrolysis of N-nitroso-N-cyclopropylamides in the presence of various substrates, one observes the formation of compounds that attest to its intermediate participation or that of its corresponding diazonium ion $C_3H_5N_2^+$. Thus, in situ generation of DCP in the presence of cyclohexadiene-1,4 [2], dicyclopropylidene [3], and cyclic ketones [4-6] leads to the formation of the corresponding spiropentanes and oxaspiropentanes, as well as of ketone homologation products, by the cyclopropylidene fragment. There are likewise examples of 1,3-dipolar addition of DCP to the double bond of α,β-unsaturated ketones of the steroid series [4, 7] to form the corresponding pyrazolines, which ordinarily retain the cyclopropane fragment.

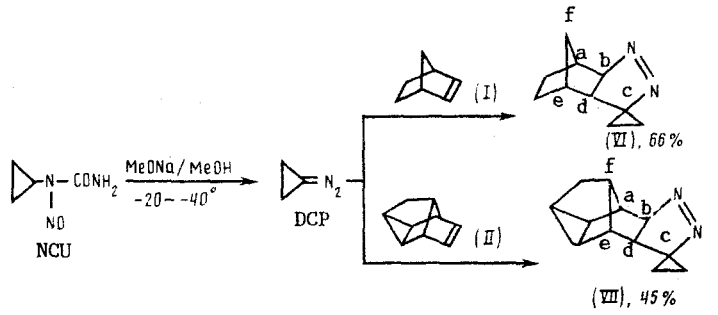
*For previous communication, see [1].

N. D. Zelinskii Institute of Organic Chemistry, Academy of Sciences of the USSR, Moscow.

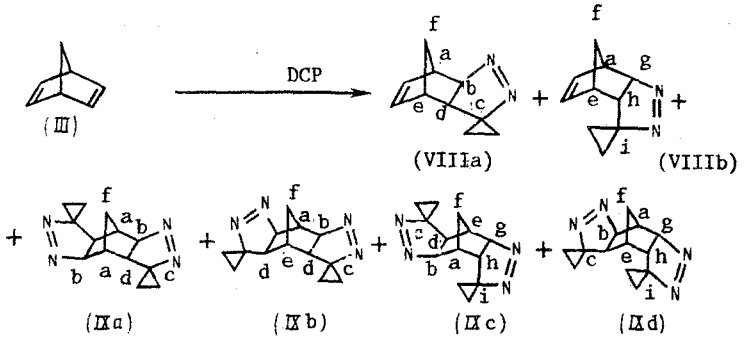
Translated from Izvestiya Akademii Nauk SSSR, Seriya Khimicheskaya, No. 5, pp. 1057-1062, May, 1991. Original article submitted May 15, 1990.

This paper reports a study of the reaction of DCP, generated in situ from N-nitroso-N-cyclopropylurea (NCU) under the action of sodium ethoxide, with the strained cyclic unsaturated hydrocarbons norbornene (I), deltacyclene (II), norbornadiene (III), and 3,3-dimethylcyclopropene (IV), as well as methylenecyclopropane (V). The reactions were carried out by slow addition of NCU to a 1.5- to 2-molar excess of MeONa in MeOH and about the same excess of unsaturated hydrocarbon in CH_2Cl_2 at −20° to −40°C. In the course of the reaction a weak evolution of gas was observed, resulting from partial deazotization of DCP with the side formation of allene and methoxycyclopropane, as shown by ^1H NMR and IR spectra. The principal products of the reaction with cyclic unsaturated hydrocarbons were the corresponding 1-pyrazolines resulting from 1,3-dipolar cycloaddition of DCP to the C=C bonds of hydrocarbons (I)-(IV).

Thus, reaction of DCP with polycyclenes (I) and (II) affords, respectively, with yields of 66 and 45% on the basis of NCU, spiro {3,4-diazatricyclo[5.2.1.$0^{2,6}$]deca-3-en-5,1'-cyclopropane} (VI) and spiro{3,4-diazapentacyclo[6.4.0.$0^{2,6}0^{7,11}0^{10,12}$]dodeca-3-en-5,1'-cyclopropane} (VII), formed exclusively as the exo isomers.



The reaction of norbornadiene (III) with DCP also proceeds as a [2 + 3]-cycloaddition, but less selectively, giving a mixture of isomeric mono- and diadducts (VIII) and (IX) with respective yields 32-35 and 35-38%. In this case the monopyrazolines (VIII), in contrast to pyrazolines (VI) and (VII), are present in a mixture of exo and endo isomers in the ratio ~4:1. The bis-pyrazolines (IXa-d) formed from them constitute a mixture of four isomers in the ratio ~10:7:1.3:1 due to the syn and anti orientation of the substituents on the diazocyclopropane fragment. The predominating exo,exo isomers (IXa) and (IXb), in the ratio ~1.4:1, were separated by crystallization from a mixture of $CHCl_3$–hexane



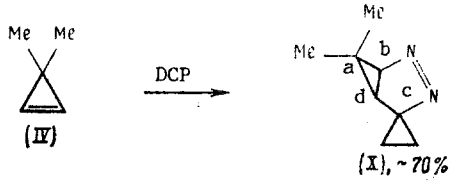
In this reaction, despite the presence of a twofold molar excess of (III), the diadducts (IX) form in even somewhat greater quantity than the monoadducts (VIII), with the addition of the second molecule of DCP to polycycles (VIIIa) and (VIIIb) occurring exclusively in the exo position.

The structure of the synthesized pyrzolines was unequivocally established by elemental analysis, ^1H NMR, and ^{13}C NMR (Table 1). Assignment of signals was by standard techniques of homo- and heteronuclear double resonance, in particular by recording ^{13}C NMR spectra from selective irradiation of protons. In ^{13}C NMR spectra, atoms C^b and C^c are deshielded to a significant degree by the diaza group and give respective signals in the 93-97 and 68-73 ppm regions. In ^1H NMR spectra of the isomers (VIIIb) and (IXc, d), the methine protons H^g and H^h of the endo-joined pyrazoline fragments give signals at lower field (Δ^δ 0.5-0.6 ppm) than the corresponding protons H^b and H^d of the exo-joined pyrazoline fragments, and in contrast

to the latter possess a vicinal spin–spin coupling constant with protons H^a and H^e of about 4-5 Hz. This value accords with the general principles for assignment of endo and exo protons in a norbornane fragment [8]. The isomers (IX) were identified using the nonequivalence of the bridgehead atoms C^a and C^e (H^a and H^e) in the syn isomer (IXb) in comparison with their counterparts in the anti isomer (IXa); the distinction was clear despite the numerous other signals. Interpretation of the minor isomers (IXc, d) is more complicated in view of the nonequivalence of all atoms in these molecules and the overlapping of many proton signals of the principal isomers. Nonetheless, the position and multiplicity of several signals identical to those of the exo isomers (IXa, b) and endo isomer (VIIIb) attest to the presence in the diadducts of exo,endo isomers (IXc) and (IXd) in the ratio ~1.3:1.

Interestingly, all the synthesized 1-pyrazolines (VI)-(IX) show considerable thermal stability. Heating to 200°C results in practically no observable product either of deazotization or of isomerization to 2-pyrazolines, which are normally more stable than the corresponding 1-pyrazolines [9]. Data on the degradation of these and several other pyrazolines under harsher conditions will be published later.

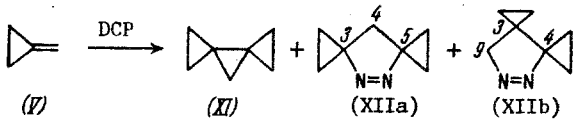
The reaction of DCP with dimethylcyclopropene (IV) proceeds analogously to its reaction with norbornene hydrocarbons. Thus, slow addition of NCU to a mixture of MeONa/MeOH–(IV)–CH_2Cl_2 at −30° to −40°C affords in ~70% yield spiro {6,6-dimethyl-2,3-diazabycyclo[3.1.0]hex-2-en-3,1'-cyclopropane} (X), the structure of which was confirmed by ^1H NMR and ^{13}C NMR (Table 1).



(IV) (X), ~70%

These results demonstrate that generation of DCP from NCU (under the usual conditions of diazoalkane synthesis) in the presence of norbornene and cyclopropene hydrocarbons is accompanied by extremely ready formation of 1-pyrazolines, products of 1,3-dipolar addition of DCP to the double bonds of hydrocarbons (I)-(IV), but not by observable formation of the spiran hydrocarbons that might be expected with symmetrically substituted double bonds by analogy with [2, 3].

In contrast with the strained cycloalkenes investigated, methylenecyclopropane (V) reacts with DCP less effectively, and besides the 1,3-cycloaddition products – the isomeric dispirodiazanonenes (XIIa) and (XIIb) in the ratio ~3:1 (overall yield ~10%) – forms the corresponding cyclopropane adduct, dispiro[2.0.2.1]heptane (XI), in ~10% yield.



(V) (XI) (XIIa) (XIIb)

EXPERIMENTAL

The synthesized compounds and their mixtures were analyzed by GLC (column 200 × 0.3 cm with 5% SP-2100 on a packing of N-Super; carrier gas He, 30 ml/min) and by GC/MS with a Finnigan MAT INCOS-50 instrument (70 eV) and a 30 m RSL-200 capillary column. The ^1H NMR and ^{13}C NMR spectra were recorded on Bruker WM-250 (250 MHz) and Jeol FX-90 Q (22.55 MHz) spectrometers in $CDCl_3$ solutions.

N-Nitroso-N-cyclopropylurea (NCU) was synthesized by addition of an aqueous solution of N-cyclopropylurea and $NaNO_2$ to dilute H_2SO_4 at 0-5°C, analogously to [10], and dried in vacuum (~1 mm) for 3 h at 20-25°C.

General Procedure for Synthesis of Polycyclic 1-Pyrazolines. To a mixture of 4.3 g (0.08 mole) MeONa, 10 ml MeOH, 10 ml CH_2Cl_2, and 0.1 mole unsaturated hydrocarbon at −40°C was added 6.5 g (0.05 mole) NCU in small portions over 30-40 min with vigorous stirring. The mixture was stirred an additional 20 min at −40° to −20°C and warmed to ∿20°C. After addition of 20 ml water, the mixture was extracted with CH_2Cl_2 (3 × 10 ml). Drying with anhydrous Na_2SO_4 and removal of the solvent was followed by fractional vacuum distillation of the residue.

TABLE 1. ^1H NMR and ^{13}C NMR Spectra of Polycyclic 1-Pyrazolines [$CDCl_3$, δ, ppm (J, Hz)]

Compound	C^a, C^e	C^b, C^g	C^c, C^i	C^d, C^h	C^f	C^*_{pc}	C^{**}_{cp}	H^a	H^b, H^g	H^d, H^h	H^e	H^f	Remaining H
(VI)	39,6 39,2	95,6	72,9	43,6	31,9	27,2 t 26,0 t	15,4 11,1	2,82 m	4,72 br.d (J_{bd} =7,3)	1,69 br.d (J_{bd}=7,3)	1,89 m	1,00 and 0,81 m (^2J=10,5)	1,02–1,15 m (3H) 1,30–1,72 m (5H)
(VII)	45,8 45,7	94,9	71,2	41,8	35,9	30,4t 14,9d 14,6 d 13,2 d	14,7 10,5	2,64 br.t (J~2,3)	5,12 br. d (J_{bd} =7,4)	2,16 br.d (J_{bd}=7,4)	1,70br.t (J~2,4)	1,39 m	0,90 and 1,08 m (H^{11}, H^{12}, $J_{10,11}$~5,6), 1,22 m (H^{10}), 1,52 m ($2H^9$), 1,03 and 1,64 m (H_{cp})**
(VIIIa)	45,4 44,5	97,2	68,4	43,4	41,9	139,2 135,4	15,7 10,8	3,42 m	4,97 br.d (J_{bd} =7,1)	1,94 br.d.d (J_{bd} =7,1, J_{df} =1,9)	2,48 m	0,99 and 1,39 m (^2J=9,5)	6,12 and 6,09 br.d.d (H^8, H^9, $J_{8,9}$=5,7, $J_{1,9}$~$J_{7,8}$=3,0), 1,06 and 1,50 m (H_{cp}) **
(VIIIb)	46,1 44,8	97,1	68,7	43,6	48,4	134,6 133,3	15,8 12,0	3,59 m	5,55 d.d (J_{gh}=8,1, J_{ag}=4,5)	2,37 d.d (J_{gh}=8,1, J_{eh}=4,0)	2,72 m	***	6,00 and 5,78 br.d.d (H^8, H^9, $J_{8,9}$=5,7, $J_{1,9}$~$J_{7,8}$=3,0), 1,06 and 1,50 m (H_{cp}) **
(IXa)	42,6	94,3	72,1	42,2	25,8		15,6 11,3	2,50 t (J=1,7)	4,71 br.d ($J_{b,d}$ = 7,4)	1,97 br.d ($J_{b,d}$ = 7,4)		0,67 br.s	1,12 and 1,70 m (H_{cp}) **

TABLE 1 (continued)

Compound	C^a, C^e	C^b, C^g	C^c, C^i	C^d, C^h	C^f	C^*_{pc}	C^{**}_{cp}	H^a	H^b, H^g	H^d, H^h	H^e	H^f	Remaining H
(IXb)	42,9	93,0	72,3	42,5	25,9		15,4 11,0	3,47 br.t (J=1,7)	4,98 br,d ($J_{b,d}$=7,5)	1,70 ***	1,57 br.t (J=1,7)	0,68 br.s	1,01 and 1,66 m (H_{cp}) **
(IXc)	43,0 41,7	93,6 90,1	73,0 67,1	42,4 36,7	33,7		15,6 15,2 12,5 10,8	2,69 m (J_{ah}=5,0)	5,19 d.d (J_{eg} =5,6, J_{gh} = 10,0) 4,86 br.d ($J_{b,d}$ =7,5)	2,31 d.d (J_{ah}=5,0) J_{gh}=10,0) 1,70 ***	2,80 m (J_{eg}=5,6)	1,31 and 1,02 m (^2J=10,5)	2,06 (1H), 1,48 (1H) (H_{cp}, J_{cis} ∿ 10,1, ^2J∿7,0, J_{trans} ∿ 5,3) remaining H_{cp} ***
(IXd)								3,74 m	5,30 d.d (J_{gh} =10,1, J_{ag} =5,1) 4,63 d.t (J_{bd} =7,6, J∿1,3)	2,14 d.d (J_{gh}=10,1, J_{eh} =4,8) 1,76 d.d (J_{bd}=7,6, J∿2,0)	***	***	***
(X)	22,1	76,0	67,5	13,5		32,6 24,0 (2Me)	14,9 10,9		4,56 d ($J_{b,d}$ = 5,5)	1,41 d ($J_{b,d}$ = 5,5)			1,14 s and 0,70 s (2Me), 1,73 m (2H), 1,37 m (1H) and 0,94 m (1H) – (H_{cp}) **

*C_{pc}: remaining C atoms in the polycyclic structure.

**C_{cp} and H_{cp}: C and H atoms in the spiro-joined cyclopropane fragment.

***Signals of the corresponding protons are obscured by signals of other protons.

Spiro{3,4-diazatricyclo[5.2.1.$0^{2,6}$]deca-3-en-5,1'-cyclopropane} (VI). Yield 66%, bp 70-71°C (0.2 mm), n_D^{20} 1.5149. Mass spectrum, m/z (I, %): 135(3), 119(10), 106(25), 105(28), 91(100). Found, %: C 74.29; H 8.61; N 17.08. $C_{10}H_{14}N_2$. Calculated, %: C 74.03; H 8.70; N 17.27. The ^1H NMR and ^{13}C NMR spectra are given in Table 1.

Spiro{3,4-diazapentacyclo[6.4.0.$0^{2,6}$.$0^{7,11}$.$0^{10,12}$]dodeca-3-en-5,1'-cyclopropane} (VII). Yield ~45%, bp 120-122°C (0.5 mm), n_D^{20} 1.5440. Mass spectrum, m/z (I, %): 157(10), 143(35), 129(100), 128(83), 117(40), 115(80), 91(92). The ^1H NMR and ^{13}C NMR spectra are given in Table 1.

Spiro{3,4-diazatricyclo[5.2.1.$0^{2,6}$]deca-3,8-dien-5,1'-cyclopropane} (VIIIa, b). Yield 32-35%, bp 82-86°C (0.4 mm), ratio of exo to endo isomers ~4:1. Mass spectrum, m/z (I, %): 160(7), 131(24), 117(88), 115(50), 104(22), 95(22), 91(100). The ^1H NMR and ^{13}C NMR spectra are given in Table 1.

Dispiro{cyclopropane-1,5'-3,4,9,10- (or 3,4,10,11)tetraazatetracyclo[5.5.1.$0^{2,6}$.$0^{8,12}$]-trideca-3,9- (or 3,10)-diene-11' (or 9'),1"-cyclopropane} (IXa-d). Yield 35-38%, bp 190-195°C (0.4 mm). A mixture of exo,exo isomers (IXa, b) in the ratio anti:syn ~1.4:1 was separated by crystallization from a mixture of hexane:$CHCl_3$ (5:1), mp 170-173°C. Found, %: C 68.52; H 7.01; N 24.23. $C_{13}H_{16}N_4$. Calculated, %: C 68.39; H 7.06; N 24.54. Assignment of signals in the ^1H NMR and ^{13}C NMR spectra of isomeric (IXa-d) is shown in Table 1.

Spiro{6,6-dimethyl-2,3-diazabicyclo[3.1.0]hex-2-ene-3,1'-cyclopropane} (X). Yield ~70%, bp 50-51.5°C (0.6 mm), n_D^{20} 1.4890. Mass spectrum, m/z (I, %): 136(11), 121(11), 93(43), 91(41), 77(55), 39(100).

Reaction of Diazocyclopropane with Methylenecyclopropane (V). The experiment was carried out analogously with the procedure described above, at −30° to −40°C. Considerable evolution of gas accompanied the reaction. When this ceased, the mixture was gently heated to ~20°C to remove the excess of (V). The resulting solution was washed with water and dried with Na_2SO_4 and most of the CH_2Cl_2 was evaporated. Residual solvent, together with volatile reaction products, was recondensed (bath temperature 50-60°C, 70 mm) in a trap chilled with dry ice. By NMR (high-field signals closely matched those in [11]) and GC/MS it was shown that the condensate contained dispiro[2.0.2.1]heptane (XI), with a yield of 10-12% based on recovered NCU. The remainder of the reaction mixture was redistilled under vacuum at 0.4 mm. Products obtained were 0.25 g (~10%) dispiro[2.1.2.2]diaza-8,9-nonane (XIIa) and dispiro-[2.0.2.3]diaza-7,8-nonane (XIIb) in the ratio ~3:1, bp 40-43°C (0.4 mm). ^1H NMR spectra ($CDCl_3$, δ, ppm) (XIIa): 1.85 s (2H), 1.58 m (4H), 0.97 m (4H); (XIIb): 4.38 s (2H), 1.42 m (2H), 0.61 m (2H), 0.50 m (2H), 0.37 m (2H). ^{13}C NMR spectra ($CDCl_3$, δ, ppm) (XIIa): 67.1 s (C^3, C^5), 32.0 t (C^4), 14.2 t (C_{cp}); (XIIb): 81.5 t (C^9), 20.4 s (C^4), 10.3 s (C^3), 9.6 t and 8.7 t (C_{cp}). Mass spectrum, m/z (I, %): 122(15), 93(17), 91(26), 79(100), 77(88).

LITERATURE CITED

1. Yu. V. Tomilov, A. B. Kostitsyn, E. V. Shulishov, and O. M. Nefedov, Izv. Akad. Nauk SSSR, Ser. Khim., No. 5, 1141 (1990).
2. C. J. Rostek and W. M. Jones, Tetrahedron Lett., No. 45, 3957 (1969).
3. I. Fitjer and J. M. Conia, Angew. Chem., 85, No. 8, 349 (1973).
4. P. Bladon and D. R. Rae, J. Chem. Soc. Perkin Trans. 1, No. 19, 2240 (1974).
5. D. R. Rae, J. Chem. Soc. Perkin Trans. 1, No. 23, 2460 (1975).
6. L. Fitjer and D. Dehle, Chem. Ber., 115, No. 3, 1061 (1982).
7. P. Bladon, D. R. Rae, and A. D. Tait, J. Chem. Soc. Perkin Trans. 1, No. 12, 1468 (1974).
8. A. J. Gordon and R. A. Ford, The Chemist's Companion, Wiley, New York (1972).
9. C. H. Jarboe, in: The Chemistry of Heterocyclic Compounds, A. Weissberger (ed.), Vol. 22, Interscience, New York (1967), p. 177.
10. Synthesis of Organic Compounds [Russian translation], Vol. 2, Izd. Inostr. Lit., Moscow (1949), p. 373.
11. N. S. Zefirov, K. A. Lukin, S. I. Kozhushkov, et al., Zh. Org. Khim., 25, No. 2, 312 (1989).