Heterocycles with a β-nitroenamine fragment

2.* Synthesis of 2-amino-3-nitropyrano[3,2-*c*]pyrans and 2-amino-3-nitropyrano[3,2-*c*]chromenes from nitroacetonitrile

V. P. Kislyi,[a] V. N. Nesterov,[b] A. M. Shestopalov,[a] and V. V. Semenov[a]*

[a]N. D. Zelinsky Institute of Organic Chemistry, Russian Academy of Sciences, 47 Leninsky prosp., 117913 Moscow, Russian Federation. Fax: +7 (095) 135 5328

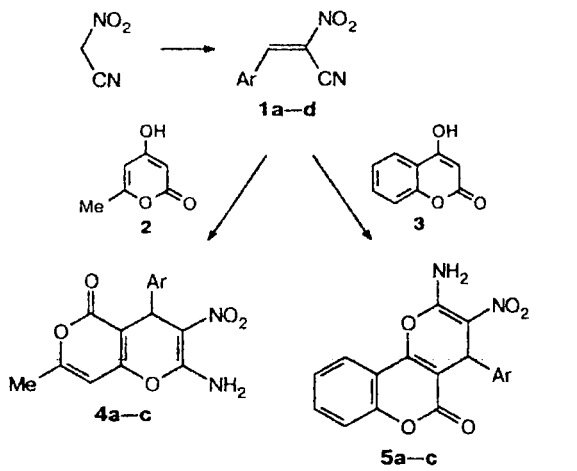
[b]A. N. Nesmeyanov Institute of Organoelement Compounds, Russian Academy of Sciences, 28 ul. Vavilova, 117813 Moscow, Russian Federation. Fax: +7 (095) 135 5085

The reactions of 4-hydroxy-6-methyl-2-pyrone and 4-hydroxycoumarin with arylidenenitroacetonitriles result in 2-amino-3-nitropyrano[3,2-*c*]pyrans and 2-amino-3-nitropyrano[3,2-*c*]chromenes, respectively. The crystal and molecular structure of one of the compounds obtained was determined by X-ray diffraction analysis.

Key words: arylidenenitroacetonitrile, 2-amino-3-nitropyrano[3,2-*c*]pyran, 2-amino-3-nitropyrano[3,2-*c*]chromene, X-ray diffraction analysis.

In the preceding communication,[1] we showed that arylidenenitroacetonitriles (ANN) react with dimedone or dihydroresorcinol to give the corresponding fused pyrans. In continuation of this investigation, we studied the reaction of ANN (**1a—e**) (which are prepared by the reaction of nitroacetonitrile with aromatic aldehydes)[2] with heterocyclic compounds containing a 1,3-diketone fragment, namely, 4-hydroxy-6-methyl-2-pyrone (**2**) and 4-hydroxycoumarin (**3**). It was shown that these reactions result in fused 2-amino-3-nitropyrano[3,2-*c*]pyrans (**4a—c**) and 2-amino-3-nitropyrano[3,2-*c*]chromenes (**5a—c**) in high yields (Scheme 1).

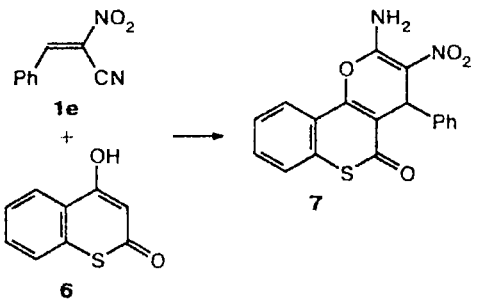
Scheme 1



1a, 4a, 5a	1b, 4b	1c, 4c, 5c	1d, 5b
Ar 2-MeOC$_6$H$_4$	3-MeOC$_6$H$_4$	4-MeOC$_6$H$_4$	3,4-methylenedioxyphenyl

The product of condensation of benzylidenenitroacetonitrile (**1e**) with 4-hydroxythiocoumarin (**6**) was pyran (**7**), unstable in DMSO-d$_6$ (Scheme 2).

Scheme 2



Other compounds such as barbituric acid, 3(5)-methylpyrazolone, and 1,3-indanedione were also assayed as dicarbonyl components, but we failed to obtain the corresponding pyrans in these reactions. We could also not reproduce the results from the published work[3], where it was reported that 4-methyl-1-phenyl-2(1*H*)-pyrazolone reacts with benzylidenenitroacetonitrile **1e** to give pyrano[3,2-*d*]pyrazole.

The structures of the compounds obtained were established by ^{1}H NMR and IR spectroscopy (Tables 1, 2). To prove decisively that the second ring is closed

* For Part 1, see Ref. 1.

Translated from *Izvestiya Akademii Nauk. Seriya Khimicheskaya*, No. 6, pp. 1146—1149, June, 1999.

1066-5285/99/4806-1135 $22.00

Table 1. Characteristics of pyrans **4**, **5**, and **7**

Compound	Yield (%)	M.p. /°C	Found / Calculated (%)			Molecular formula	IR, ν/cm^{-1}
			C	H	N		
4a	30	250—251	58.12 58.18	4.10 4.27	8.31 8.48	$C_{16}H_{14}N_2O_6$	3400—3300 (NH_2), 1680—1630 (CO), 1510 $\nu_{as}(NO_2)$
4b	70	205—208	58.31 58.18	4.02 4.27	8.15 8.48	$C_{16}H_{14}N_2O_6$	3400—3200 (NH_2), 1670—1640 (CO), 1510 $\nu_{as}(NO_2)$
4c	65	240	58.50 58.18	4.33 4.27	8.82 8.48	$C_{16}H_{14}N_2O_6$	3400—3200 (NH_2), 1670—1630 (CO), 1505 $\nu_{as}(NO_2)$
5a	80	253—256	62.01 62.30	3.87 3.85	7.91 7.65	$C_{19}H_{14}N_2O_6$	3400—3200 (NH_2), 1670 + 1720 (CO), 1495 $\nu_{as}(NO_2)$
5b	80	262—263	60.41 60.01	3.33 3.18	7.52 7.37	$C_{19}H_{12}N_2O_7$	3400—3200 (NH_2), 1670 + 1720 (CO), 1510 $\nu_{as}(NO_2)$
5c	85	265	62.33 62.30	3.74 3.85	7.61 7.65	$C_{19}H_{14}N_2O_6$	3450—3200 (NH_2), 1680 + 1720, 1490 $\nu_{as}(NO_2)$
7	73	265	61.43 61.36	3.51 3.43	7.82 7.95	$C_{18}H_{12}N_2O_4S$	3400—3250 (NH_2), 1670 + 1700 (CO), 1495 $\nu_{as}(NO_2)$

Table 2. ^{1}H NMR spectra (δ) of pyrans **4**, **5**, and **7**

Compound	2-NH_2 (br.s)	4-H (s)	7-CH_3 (s)	Other signals*	Aromatic protons
4a	9.4	4.91	2.27	3.75 (s, 3 H)	6.3 (s, 1 H); 6.8 (m, 3 H); 7.2 (t, 1 H)
4b	9.35	4.92	2.25	3.7 (s, 3 H)	6.27 (s, 1 H); 6.8 (m, 2 H); 7.2 (t, 1 H); 7.35 (d, 1 H)
4c	9.4	4.90	2.3	3.73 (s, 3 H)	6.3 (s, 1 H); 6.8 (d, 2 H); 7.15 (d, 2 H)
5a	9.6	5.1	—	3.6 (s, 3 H)	6.9 (m, 2 H); 7.2 (t, 1 H); 7.4—7.6 (m, 3 H); 7.7 (t, 1 H); 8.0 (d, 1 H)
5b	9.5	5.1	—	5.95 (s, 2 H)	6.7 (d, 1 H); 6.8 (d, 1 H); 6.85 (s, 1 H); 7.45 (m, 2 H); 7.7 (t, 1 H); 8.0 (d, 1 H)
5c	9.6	5.05	—	3.7 (s, 3 H)	6.8 (d, 2 H); 7.2 (d, 2 H); 7.5 (m, 2 H); 7.7 (t, 1 H); 8.0 (d, 1 H)
7	9.55	4.85	—	—	8.5 (d, 1 H); 7.6—7.8 (m, 3 H); 7.2—7.3 (m, 5 H)

* OMe for **4a—c** and **5a,c** and —OCH_2O— for **5b**.

with the involvement of the oxygen atom at C(4) rather than that at C(2), compound **4a** was studied by X-ray diffraction analysis. Figure 1 illustrates the general view of the molecule. Bond lengths and bond angles are listed in Tables 3 and 4, respectively.

The pyran heterocycle in the molecule under study has the boat conformation: the O(1) and C(4) atoms deviate from the "boat bottom" plane (the bottom is planar with an accuracy of 0.003 Å) by 0.147 and 0.216 Å, respectively, and the dihedral angles of the ring along the C(2)...C(8A), C(3)...C(4A), and O(1)...C(4) lines are equal to 12.3°, 14.1°, and 17.1°. A larger dihedral angle in the 4*H*-pyran ring favors the occurrence in the crystal of a conformer with *anti*-periplanar arrangement of the pseudoaxial *ortho*-methoxyphenyl substituent with respect to the hydrogen atom at C(4) (H(4)—C(4)—C(9)—C(10) and C(4)—C(9)—C(10)—O(4) torsion angles are equal to −179.4° and 1.5°, respectively). Such an orientation of the aryl substituent gives rise to the induced shortened nonvalence intramolecular contacts O(4)...C(2) 3.035(3) Å, O(4)...C(3) 2.961(3) Å, O(4)...C(4A) 2.806(3) Å, and O(4)...C(8A) 3.038(3) Å (the sum of the van der Waals radii of O and C is 3.31 Å),[4] which stabilize the orthogonal arrangement of the substituent with respect to the "boat bottom" of the heterocycle (the dihedral angle is equal to 91.6°). The dihedral angle between the planar pyranone heterocycle and the "boat bottom" of the 4*H*-pyran ring is equal to 8.6°, which indicates that this fragment is flattened. The NO_2 and NH_2 groups also lie in the "boat bottom" plane, which results in formation of the strong intramolecular N(1)—H(1.1)...O(2) hydrogen bond with the following parameters: N(1)...O(2) 2.642(3) Å, N(1)—H(1.1) 0.87(2) Å, H(1.1)...O(2) 2.02(2) Å, N(1)—H(1.1)...O(2) 128(2)°. The planar structure of the N(1)—C(2)=C(3)—N(2)—O(2) fragment (the deviation of the atoms from the average plane does not exceed 0.006 Å) is favorable for conjugation. Thus, the valence distances N(1)—C(2) 1.314(3) Å and C(3)—N(2) 1.389(3) Å are much shorter than the usual ones (the conjugated $C(sp^2)$—$N(sp^2)$ and $C(sp^2)$—NO_2 bond lengths are equal to 1.336 Å and 1.468 Å, respectively),[5] while the C(2)=C(3) bond (1.388(3) Å) is significantly longer than the C(4A)=C(8A) bond (1.340(3) Å) and so is the

N(2)—O(2) bond (1.254(3) Å) (the standard values of the $C(sp^2)$=$C(sp^2)$ and $N(sp^2)$—O (in the NO_2 group) bond lengths are equal to 1.331 and 1.218 Å, respectively).[5] Apparently, the O(1) atom is also involved in conjugation with the C(2)=C(3) double bond, which is evidenced by shortening of the O(1)—C(2) bond to 1.358(3) Å, as compared to the O(1)—C(8A) bond (1.375(2) Å). The dihedral angle between this planar fragment and the "boat bottom" of the heterocycle is equal to 7.8°. Thus, the entire fragment under discussion of the molecule is markedly flattened. An analogous structure with similar rearrangement of valence distances and formation of a strong intramolecular H-bond were found by us in related compounds.[1,6]

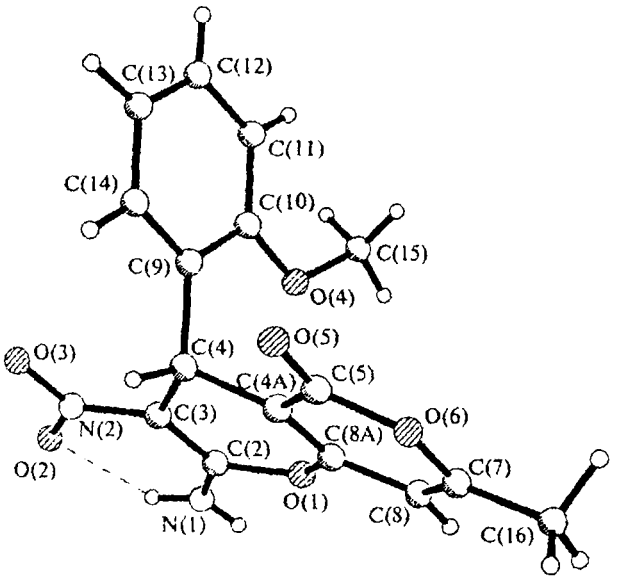


Fig. 1. General view of molecule **4a**. The intramolecular N—H...O hydrogen bond is indicated by the dotted line.

Table 3. Bond lengths (*d*) in molecule **4a**

Bond	*d*/Å	Bond	*d*/Å
O(1)—C(2)	1.358(3)	C(4)—C(4A)	1.508(3)
O(1)—C(8A)	1.375(2)	C(4)—C(9)	1.529(3)
O(2)—N(2)	1.254(2)	C(4A)—C(8A)	1.340(3)
O(3)—N(2)	1.256(2)	C(4A)—C(5)	1.445(3)
O(4)—C(10)	1.369(3)	C(7)—C(8)	1.336(3)
O(4)—C(15)	1.419(3)	C(7)—C(16)	1.485(3)
O(5)—C(5)	1.195(3)	C(8)—C(8A)	1.421(3)
O(6)—C(7)	1.362(3)	C(9)—C(14)	1.385(3)
O(6)—C(5)	1.396(3)	C(9)—C(10)	1.406(3)
N(1)—C(2)	1.314(3)	C(10)—C(11)	1.390(3)
N(2)—C(3)	1.389(3)	C(11)—C(12)	1.386(4)
C(2)—C(3)	1.388(3)	C(12)—C(13)	1.375(4)
C(3)—C(4)	1.512(3)	C(13)—C(14)	1.387(4)

Table 4. Bond angles (ω) in molecule **4a**

Angle	ω/deg	Angle	ω/deg
C(2)—O(1)—C(8A)	119.2(2)	O(5)—C(5)—C(4A)	126.9(2)
C(10)—O(4)—C(15)	117.5(2)	O(6)—C(5)—C(4A)	116.3(2)
C(7)—O(6)—C(5)	123.2(2)	C(8)—C(7)—O(6)	120.7(2)
O(2)—N(2)—O(3)	120.7(2)	C(8)—C(7)—C(16)	127.4(2)
O(2)—N(2)—C(3)	121.2(2)	O(6)—C(7)—C(16)	111.9(2)
O(3)—N(2)—C(3)	118.1(2)	C(7)—C(8)—C(8A)	118.0(2)
N(1)—C(2)—O(1)	109.9(2)	C(4A)—C(8A)—O(1)	122.5(2)
N(1)—C(2)—C(3)	129.7(2)	C(4A)—C(8A)—C(8)	123.4(2)
O(1)—C(2)—C(3)	120.4(2)	O(1)—C(8A)—C(8)	114.1(2)
C(2)—C(3)—N(2)	119.7(2)	C(14)—C(9)—C(10)	118.7(2)
C(2)—C(3)—C(4)	123.0(2)	C(14)—C(9)—C(4)	119.8(2)
N(2)—C(3)—C(4)	117.3(2)	C(10)—C(9)—C(4)	121.5(2)
C(4A)—C(4)—C(3)	108.0(2)	O(4)—C(10)—C(11)	124.3(2)
C(4A)—C(4)—C(9)	112.0(2)	O(4)—C(10)—C(9)	116.0(2)
C(3)—C(4)—C(9)	114.2(2)	C(11)—C(10)—C(9)	119.7(2)
C(8A)—C(4A)—C(5)	118.3(2)	C(12)—C(11)—C(10)	119.9(2)
C(8A)—C(4A)—C(4)	122.9(2)	C(13)—C(12)—C(11)	121.2(2)
C(5)—C(4A)—C(4)	118.7(2)	C(12)—C(13)—C(14)	118.8(2)
O(5)—C(5)—O(6)	116.8(2)	C(9)—C(14)—C(13)	121.7(2)

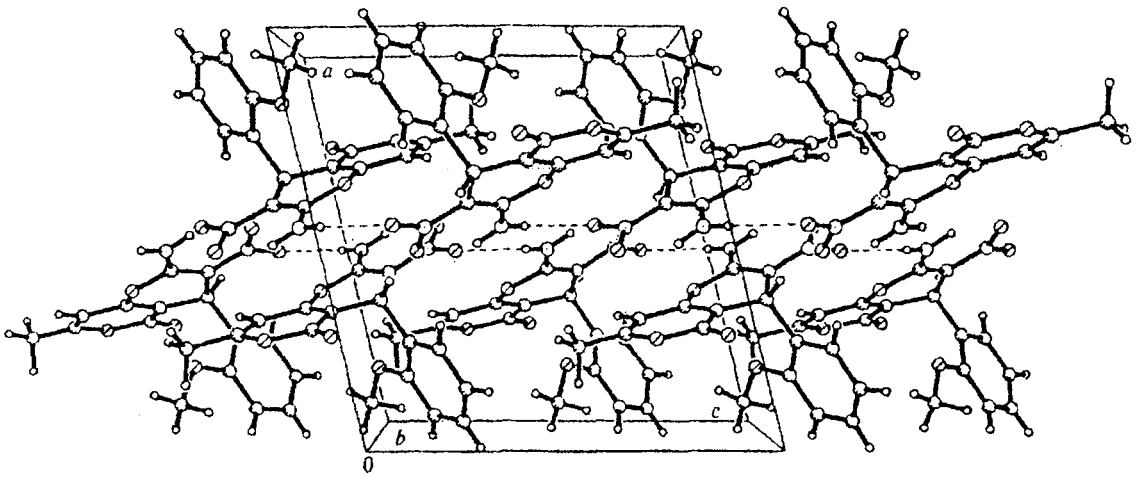


Fig. 2. The *ac* projection of crystal structure **4a**. The intermolecular N—H...O hydrogen bonds are indicated by dotted lines.

Table 5. Atomic coordinates ($\times 10^4$) and isotropic equivalent (isotropic for H atoms) thermal parameters in molecule **4a**

Atom	*x*	*y*	*z*	U/Å^2	Atom	*x*	*y*	*z*	U/Å^2
O(1)	6376(2)	−2066(1)	5809(1)	39(1)	C(12)	9650(2)	51(3)	2720(3)	53(1)
O(2)	4696(1)	−2384(2)	2265(2)	46(1)	C(13)	8784(2)	883(2)	2404(2)	49(1)
O(3)	5324(2)	−646(2)	1881(1)	44(1)	C(14)	7798(2)	782(2)	2863(2)	39(1)
O(4)	8376(2)	−1872(2)	4683(2)	46(1)	C(15)	9321(3)	−2645(3)	5148(3)	60(1)
O(5)	7406(2)	1942(2)	5459(2)	60(1)	C(16)	7748(3)	522(3)	9263(3)	55(1)
O(6)	7535(2)	1131(1)	7246(2)	43(1)	H(1.1)	4869(26)	−3384(27)	3760(30)	49(8)
N(1)	5287(2)	−3233(2)	4480(2)	44(1)	H(1.2)	5297(28)	−3642(31)	5053(33)	57(9)
N(2)	5267(2)	−1462(2)	2611(2)	35(1)	H(4)	6069(22)	516(23)	3737(23)	37(7)
C(2)	5813(2)	−2201(2)	4636(2)	34(1)	H(8)	7024(26)	−1544(28)	8008(29)	53(8)
C(3)	5868(2)	−1322(2)	3802(2)	32(1)	H(11)	10114(29)	−1461(28)	3687(29)	56(8)
C(4)	6571(2)	−201(2)	4122(2)	31(1)	H(12)	10310(32)	53(32)	2430(33)	73(10)
C(4A)	6856(2)	−68(2)	5473(2)	32(1)	H(13)	8815(25)	1546(27)	1833(27)	51(8)
C(5)	7271(2)	1062(2)	5991(2)	39(1)	H(14)	7184(28)	1373(29)	2669(29)	59(9)
C(7)	7438(2)	195(2)	7968(2)	39(1)	H(151)	9503(30)	−3145(31)	4433(33)	68(10)
C(8)	7087(2)	−862(2)	7494(2)	37(1)	H(152)	10008(30)	−2216(29)	5521(31)	58(9)
C(8A)	6777(2)	−964(2)	6219(2)	32(1)	H(153)	9064(33)	−3158(34)	5697(34)	73(11)
C(9)	7663(2)	−141(2)	3618(2)	32(1)	H(161)	7611(31)	−135(35)	9756(34)	71(10)
C(10)	8557(2)	−986(2)	3930(2)	36(1)	H(162)	8655(36)	638(34)	9486(36)	82(11)
C(11)	9548(2)	−884(2)	3475(3)	49(1)	H(163)	7301(40)	1164(43)	9440(43)	97(13)

The reciprocal orientation of the substituents observed in the molecule results in the intramolecular H(4)...O(3) nonvalence contact (2.47(2) Å), which is comparable with the sum of the van der Waals radii of these atoms.[4]

In the crystal, intermolecular N(1)—H(1.2)...O(3) (x, $-0.5 - y$, $0.5 + z$) hydrogen bonds [N(1)...O(3) 3.012(3) Å, N(1)—H(1.2) 0.80(2) Å, H(1.2)...O(3) 2.23(2) Å, N(1)—H(1.2)...O(3) 166(2)°] combine molecules **4a** into infinite chains (Fig. 2).

Experimental

^{1}H NMR spectra were recorded on a Bruker WM-250 instrument (250.13 MHz) in DMSO-d_6. IR spectra were recorded on a Perkin—Elmer 457 instrument (KBr).

Synthesis of pyrans (general procedure). A mixture of equimolar amounts of arylidenenitroacetonitriles **1a—d** and 4-hydroxy-6-methylpyrone or 4-hydroxycoumarin was heated to dissolution in a minimum amount of ethanol. A drop of Et_3N was added, and the reaction mixture was left overnight. The crystals that formed were filtered off, washed with methanol, and dried in a vacuum exsiccator.

X-ray diffraction analysis. The crystals of **4a** are monoclinic, a = 11.799(3) Å, b = 11.304(2) Å, c = 11.419(3) Å, β = 103.47(2)°, V = 1481.2(6) Å^3, d_{calc} = 1.481 g cm^{-3} (25 °C), Z = 4, space group $P2_1/c$. The unit cell parameters and the intensity data were measured from 3427 reflections on a Siemens P3/PC four-circle automatic diffractometer (λ(Mo-Kα), graphite monochromator, θ/θ scanning until θ_{max} = 28°). The structure was solved by the direct method with location of all nonhydrogen atoms and refined by the full-matrix least-squares method in the anisotropic approximation for nonhydrogen atoms. All hydrogen atoms were located in an objective manner by differential Fourier syntheses and refined isotropically. The final residuals R_1 = 0.059 from 2568 independent reflections with $I > 2\sigma$, wR_2 = 0.200 from 3206 reflections. All computations were performed with the SHELXTL PLUS and SHELXTL-93 programs (PC version). Atomic coordinates and isotropic equivalent (isotropic for H atoms) thermal parameters are given in Table 5.

X-ray diffraction analysis was financially supported by the Russian Foundation for Basic Research (Project Nos. 97-03-33783 and 96-15-97367).

References

1. V. P. Kislyi, V. N. Nesterov, A. M. Shestopalov, and V. V. Semenov, *Izv. Akad. Nauk, Ser. Khim.*, 1999, 1142 [*Russ. Chem. Bull.*, 1999, **48**, 1127 (Engl. Transl.)].
2. W. Ried and E. Kohler, *Lieb. Ann.*, 1956, **598**, 145.
3. A. S. Polyanskaya, R. I. Bodina, V. Yu. Shchadrin, and N. I. Aboskalova, *Zh. Org. Khim.*, 1984, **20**, 2481 [*J. Org. Chem. USSR*, 1984, **20** (Engl. Transl.)].
4. R. S. Rowland and R. Taylor, *J. Phys. Chem.*, 1996, **100**, 7384.
5. F. H. Allen, O. Kennard, D. G. Watson, L. Brammer, A. G. Orpen, and R. Taylor, *J. Chem. Soc., Perkin Trans. 2*, 1987, 1.
6. V. P. Kislyi, V. N. Nesterov, A. M. Shestopalov, and V. V. Semenov, *Izv. Akad. Nauk, Ser. Khim.*, 1999, 1150 [*Russ. Chem. Bull.*, 1999, **48**, 1135 (Engl. Transl.)].

Received June 22, 1998;
in revised form January 20, 1999