8-R-5,7-Dinitroquinolines in [3+2] cycloaddition reactions with *N*-methylazomethine ylide*

M. A. Bastrakov,[a] A. I. Leonov,[a] A. M. Starosotnikov,[a] I. V. Fedyanin,[b] and S. A. Shevelev[a]*

[a]*N. D. Zelinsky Institute of Organic Chemistry, Russian Academy of Sciences, 47 Leninsky prosp., 119991 Moscow, Russian Federation. Fax: +7 (499) 135 5328. E-mail: b_max82@mail.ru*
[b]*A. N. Nesmeyanov Institute of Organoelement Compounds, Russian Academy of Sciences, 28 ul. Vavilova, 119991 Moscow, Russian Federation. Fax: +7 (499) 135 6549. E-mail: octy@xrlab.ineos.ac.ru*

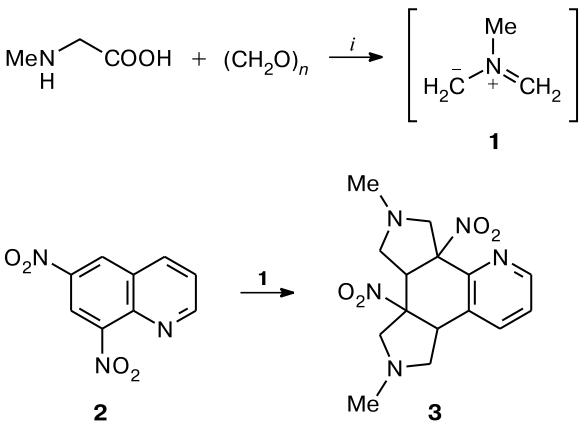
Novel derivatives of isoindole and dihydroisoindole fused to the pyridine ring were obtained by 1,3-dipolar cycloaddition reactions of *N*-methylazomethine ylide with substituted 5,7-dinitroquinolines. The substituents in the benzene ring were found to affect the cycloaddition outcome.

Key words: 1,3-dipolar cycloaddition, quinolines, nitro compounds, azomethine ylides, polycyclic systems.

[3+2] Cycloaddition reactions are among key tools in modern heterocyclic chemistry.[1] The present paper is the first one in a series of publications concerned with systematic investigations of 1,3-dipolar cycloaddition to benzene-fused azines containing one or two nitro groups in the benzene ring.

Recently, we have reported on the first example of [3+2] cycloaddition reactions of *N*-methylazomethine ylide (**1**) with nitroarenes.[2,3] We have studied mainly mono- and dinitrobenzoazoles and 6,8-dinitroquinoline (**2**) as a representative of the azine series. *N*-Methylazomethine ylide (**1**) used as a 1,3-dipole was generated *in situ* from paraformaldehyde and sarcosine in boiling toluene (Scheme 1).

Scheme 1



i. PhMe, 110 °C.

In all cases, the cycloaddition occurred at the aromatic carbon—carbon bonds activated by the nitro groups in the starting nitroarene, yielding the pyrrolidine (*e.g.*, compound **3**) or pyrroline ring.

In the next step of these investigations, we found it interesting to study the pathways and regularities of [3+2] cycloaddition reactions in the series of dinitrobenzenes fused to six-membered heterocycles (*e.g.*, pyridine). Here we studied derivatives of 5,7-dinitroquinoline, which is a structural isomer of 6,8-dinitroquinoline. Investigations of such structures are important and meet current challenges because many quinoline derivatives exhibit useful biological activity. The quinoline fragment is part of many alkaloids and drugs.[4] In particular, nitroxalin (or 8-hydroxy-5-nitroquinoline) is commercially produced by modern pharmaceutical industry. This broad-spectrum therapeutic agent is efficient against some Gram-positive and Gram-negative bacteria and *Candida* and other fungi.[5]

Chloride **4** (see Refs 6, 7), which can be prepared from commercial 8-hydroxyquinoline, was employed as a starting material for the synthesis of 8-R-5,7-dinitroquinolines. The Cl atom in compound **4** is a good leaving group that can be displaced by many nucleophiles.[7—11] We used this structural feature to obtain quinolines **5**—**16** (Scheme 2, Table 1).

The compounds obtained were studied in 1,3-dipolar cycloaddition reactions with *N*-methylazomethine ylide.

* Dedicated to Academician of the Russian Academy of Sciences I. P. Beletskaya on the occasion of her anniversary.

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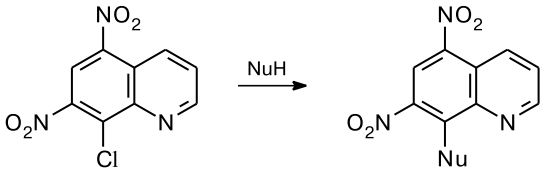
Table 1. Reaction conditions and yields of the nucleophilic substitution products from chloride **4**

NuH	Reaction conditions			Reaction product	Yield (%)
	Solvent	*T*/°C	*t*/h		
PhSH	Et_3N, DME	20	1	**5**	88
BnSH	Et_3N, DME	20	1	**6**	86
2-Furylmethanethiol	Et_3N, DME	20	2	**7**	74
cyclo-C_6H_{11}—SH	Et_3N, DME	20	1.5	**8**	58
4-Cl—C_6H_4—SH	Et_3N, DME	20	1	**9**	83
$HSCH_2CO_2Me$	Et_3N, DME	20	0.5	**10**	63
PhOH	Na_2CO_3, CH_3CN	81	2	**11**	89
MeOH	MeONa, MeOH	65	1.5	**12**	99
Me_2NH	MeOH	20	1	**13**	85
Piperidine	EtOH	20	1.5	**14**	86
Morpholine	EtOH	20	1.5	**15**	90
4-Cl—C_6H_4—NH_2	EtOH	20	2.5	**16**	85

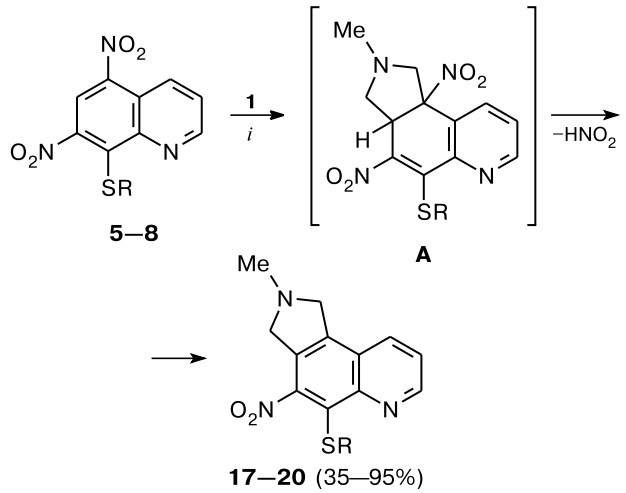
Scheme 2



4 **5—16**

We found that the cycloaddition to sulfides **5—8** occurs only at the C(5)—C(6) bond activated by the nitro group. Apparently, the reaction involves the formation of tricyclic intermediates **A**, which promptly undergo *in situ* aromatization with elimination of HNO_2. Thus, we synthesized new pyrroline derivatives **17—20** (Scheme 3).

Scheme 3



5—8 **A**

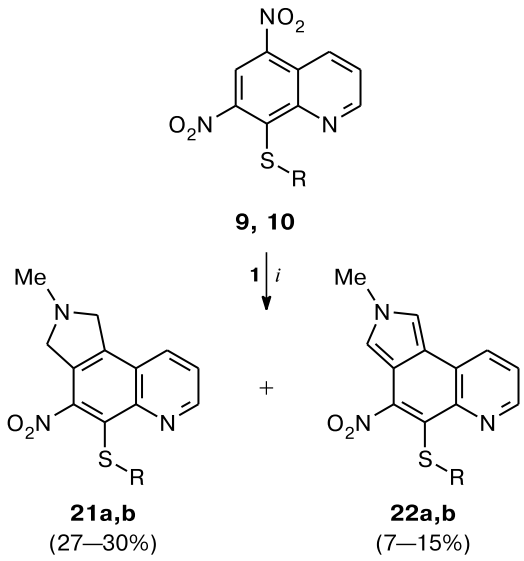
17—20 (35—95%)

R = Ph (**17**), Bn (**18**), *cyclo*-C_6H_{11} (**19**), furfuryl (**20**)

i. PhMe, 110 °C.

The reactions with sulfides **9** and **10** gave not only the expected pyrrolines **21a**,**b** but also their oxidation products, *viz.*, pyrroles **22a**,**b** (Scheme 4).

Scheme 4



21a,b (27—30%) **22a,b** (7—15%)

R = 4-ClC_6H_4 (**9**, **21a**, **22a**), CH_2CO_2Me (**10**, **21b**, **22b**)

i. PhMe, reflux.

The structures of all the compounds obtained as well as the cycloaddition pathway were confirmed by NMR spectroscopy and X-ray diffraction data for tricyclic product **18** (Fig. 1).

The crystal structures of such fused quinoline-based heterocycles have not yet been described. The geometrical parameters of their structural fragments are close to the average values in known compounds (Table 2). The cyclic fragment of structure **18** in the crystal shows a significantly nonplanar conformation of the quinoline ring: the tor-

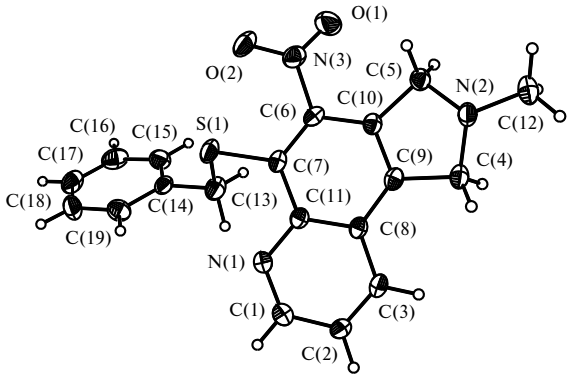


Fig. 1. Molecular structure of compound **18** with atomic displacement ellipsoids ($p = 50\%$) (X-ray diffraction data).

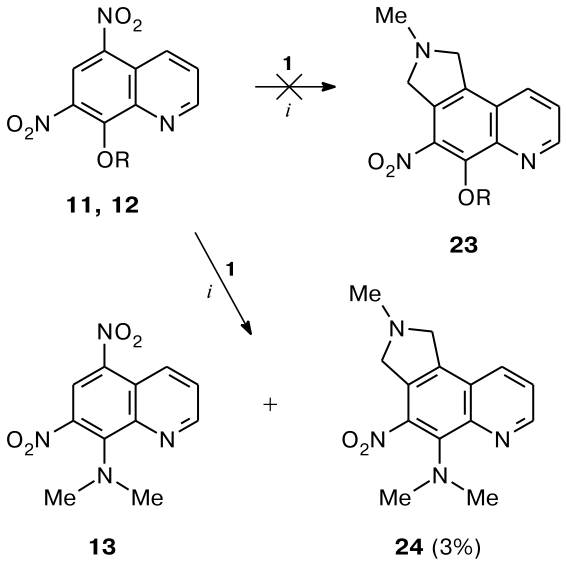
Table 2. Selected bond lengths and bond angles in the crystal structures of compounds **18** and **24** (X-ray diffraction data)

Parameter	**18**	**24**
Bond	*d*/Å	
N(1)—C(1)	1.315(3)	1.322(1)
C(1)—C(2)	1.412(3)	1.410(2)
C(2)—C(3)	1.355(3)	1.370(1)
C(3)—C(8)	1.413(3)	1.416(1)
C(4)—N(2)	1.468(3)	1.470(1)
C(5)—C(10)	1.498(3)	1.507(1)
C(5)—N(2)	1.469(2)	1.471(1)
C(8)—C(9)	1.407(3)	1.418(1)
C(9)—C(4)	1.510(3)	1.504(1)
C(6)—C(7)	1.379(3)	1.400(1)
C(7)—C(11)	1.440(3)	1.459(1)
C(8)—C(11)	1.431(3)	1.423(1)
C(9)—C(10)	1.361(3)	1.367(1)
C(10)—C(6)	1.413(3)	1.417(1)
N(2)—C(12)	1.457(2)	1.453(1)
C(6)—N(3)	1.468(3)	1.458(1)
C(7)—S(1)	1.768(2)	—
C(7)—N(4)		1.377(1)
Angle	ω/deg	
C(1)—N(1)—C(11)	117.8(2)	118.21(9)
C(1)—C(2)—C(3)	119.0(2)	118.47(9)
C(3)—C(8)—C(9)	123.9(2)	122.52(9)
C(4)—C(9)—C(8)	128.7(2)	129.31(9)
C(4)—N(2)—C(5)	108.4(2)	108.20(8)
C(4)—N(2)—C(12)	114.2(2)	114.95(8)
N(2)—C(4)—C(9)	102.0(2)	101.92(8)
C(5)—N(2)—C(12)	113.1(2)	113.78(8)
C(5)—C(10)—C(6)	130.4(2)	130.73(9)
C(6)—C(7)—S(1)	122.4(2)	—
C(7)—C(6)—C(10)	122.6(2)	122.85(9)
C(7)—S(1)—C(13)	101.2(9)	—
S(1)—C(13)—C(14)	108.0(2)	—
C(7)—N(4)—C(13)	—	121.99(8)
C(13)—N(4)—C(14)	—	113.09(8)

sion angle C(1)—C(2)—C(10)—C(6), which is a twist distortion indicator, is 4.18(2)° and the N(1) atom deviates from the plane of the second aromatic ring C(6)C(7)C(11)C(8)C(9)C(10) by 0.104(3) Å. The five-membered ring adopts an envelope conformation: the N(2) atom is off the plane as far as 0.406(3) Å. As expected, the geometry of the N(2) atom is pyramidal (the sum of the angles is 335.7(5)°). The nitro group makes a considerable angle with the plane of the quinoline ring: the characteristic torsion angle C(7)—C(6)—N(3)—O(2) is 37.8(3)°. Since the atoms of the nitro group in the crystal packing are not involved in strong intermolecular interactions (the O...H distance for the shortest C—H...O contact is 2.528 Å), the observed rotation of the nitro group is probably due to the intramolecular interaction S(1)...O(2) (2.847(2) Å). This value is much lower than the sum of the van der Waals radii of the oxygen and sulfur atoms (3.32 Å).

Unexpected results were obtained in the attempted cycloaddition of *N*-methylazomethine ylide to 8-RO-quinolines. For instance, reactions of compounds **11** and **12** with sarcosine and paraformaldehyde in boiling toluene gave amine **13** as the major product rather than the expected pyrrolines **23** (Scheme 5).

Scheme 5



R = Me, Ph

i. PhMe, 110 °C.

In addition, adduct **24** was obtained in minor amounts (3%); its structure was confirmed by NMR spectroscopy and X-ray diffraction (Fig. 2).

The molecular geometry of structure **24** (see Table 2) in the crystal is similar to that of compound **18**: the five-membered ring adopts an envelope conformation with the N(2) atom deviating by 0.415(2) Å from the plane of the

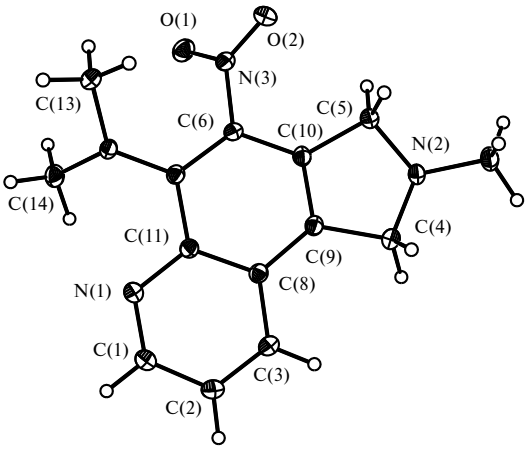


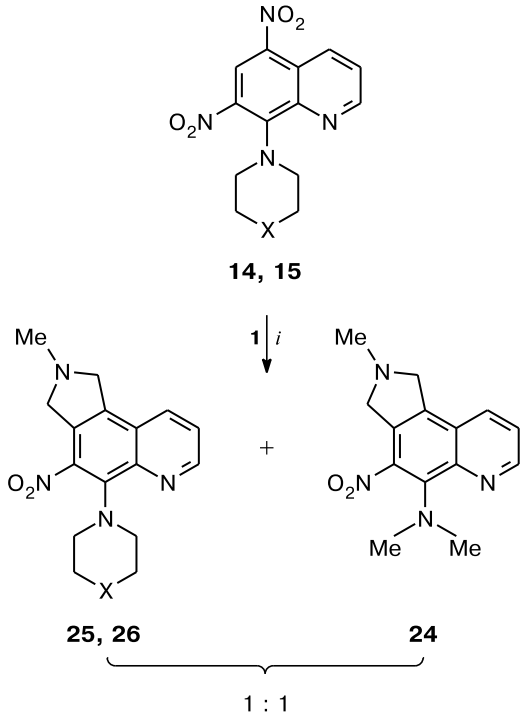
Fig. 2. Molecular structure of compound **24** with atomic displacement ellipsoids (p = 50%) (X-ray diffraction data).

carbon atoms; the sum of the angles at the pyramidal N(2) atom is 336.9(2) . The quinoline framework is also considerably distorted: the angle C(1)—C(2)—C(10)—C(6) is 6.12(4)°. As in the crystal structure of compound **18**, the nitro group makes an angle with the plane of the quinoline ring: the torsion angle C(7)—C(6)—N(3)—O(1) (–38.0(2)°) is due to steric interactions of the O atom of the nitro group with the H atoms of the dimethylamino substituent. In contrast to structure **18**, the latter interactions result in substantial deviations of the exocyclic N atoms in both the nitro (by 0.300(2) Å) and dimethylamino groups (by 0.245(2) Å) from the plane of their parent six-membered ring. This in turn makes the C(6)—N(3) bond in compound **24** longer by 0.010(4) Å than that in compound **18** (1.468(3) against 1.458(1) Å, respectively). The crystal packing of structure **24** shows the weak contacts N—H...O and C—H...O as well as fairly strong intermolecular stacking in pairs between the C(2) and C(1) atoms of the quinoline rings (C...C, 3.361(3) Å).

Reactions of 8-aminoquinolines **14** and **15** with sarcosine and paraformaldehyde in boiling toluene produce an inseparable 1 : 1 mixture of pyrrolines **24** and **25** (or **24** and **26**); *i.e.*, as with 8-RO-quinolines, the expected tricyclic products **25** and **26** are formed together with compound **24** (Scheme 6). Products **25** and **26** were identified by NMR spectroscopy, LC-MS, and high-resolution mass spectrometry.

Interestingly, the conversion of quinoline **13** in a reaction with azomethine ylide **1** was incomplete even when the starting compound was refluxed with multiple excesses of sarcosine and paraformaldehyde for a long period of time. The yield of pyrroline **24** was 43% (Scheme 7).

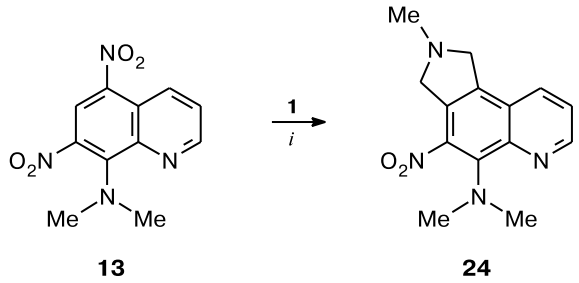
Scheme 6



X = CH_2 (**14**, **25**), O (**15**, **26**)

i. PhMe, 110 °C.

Scheme 7

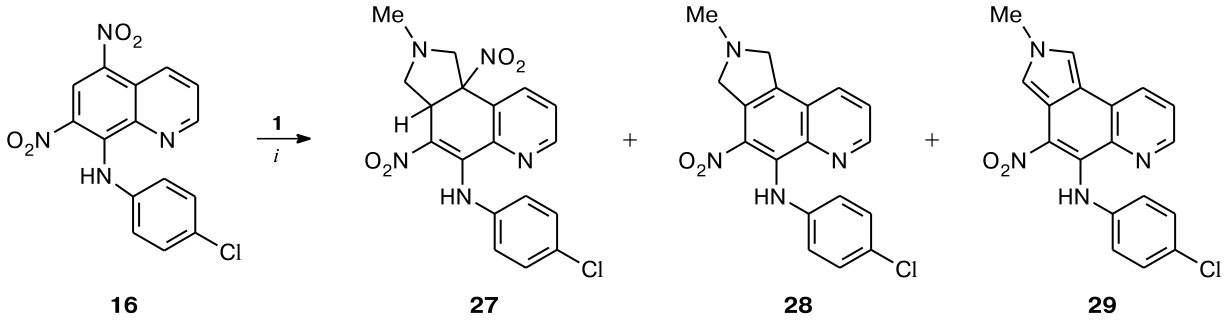


i. PhMe, 110 °C.

We found that replacement of an aliphatic amine by an aromatic one substantially affects the course and pathway of the cycloaddition. For instance, a reaction of amine **16** with sarcosine and paraformaldehyde under standard conditions (toluene, 110 °C) gives, immediately after the complete consumption of the starting compound, adduct **27** and its aromatization products **28** and **29** (Scheme 8), which were isolated and identified. However, reflux of the same reaction mixture for 144 h leads to a different ratio of these three products (Table 3).

To sum up, using 1,3-dipolar cycloaddition reactions of *N*-methylazomethine ylide with substituted 5,7-dinitroquinolines, we obtained new derivatives of dihydroisoindole and isoindole fused to the pyridine ring. We also found that the substituents in the benzene ring affect the cycloaddition outcome.

Scheme 8



16 **27** **28** **29**

i. PhMe, 110 °C.

Table 3. Reaction times of the cycloaddition to compound **16** and the yields of the products

Reaction time	Yields of the products (%)		
	27	**28**	**29**
6 h	59	33	4
144 h	3	67	15

In conclusion, it is worth noting that 1,3-dipolar cycloaddition to the C=N bond of the pyridine ring should not be ruled out because cycloaddition to this bond of some azines has been reported.[12,13] However, we never observed this process in our experiments under discussion.

Experimental

^{1}H and ^{13}C NMR spectra were recorded on Bruker AC-200 (200 (^{1}H) and 50 MHz (^{13}C)) and Bruker AM-300 instruments (300 (^{1}H) and 75 MHz (^{13}C)) in DMSO-d_6 or $CDCl_3$. All experiments were performed according to Bruker standard procedures. Chemical shifts δ are referenced to Me_4Si. LC-MS spectra were recorded on an Agilent 1200 Series high-efficiency liquid chromatograph fitted with a Maxis mass-selective detector (Bruker); for liquid chromatography, acetonitrile—(H_2O + CF_3COOH) (90 : 10) was used as an eluent. High-resolution mass spectra were measured on a Bruker maXis instrument (ESI, positive ion detection, capillary voltage 4500 V)[14] for an *m/z* scan range of 50—3000 Da. The instrument was calibrated externally using an Electrospray Calibrant Solution (Fluka). Samples were dissolved in acetonitrile and infused through a syringe into the mass spectrometer at a flow rate of 3 μL min^{-1}. Nitrogen was employed as a nebulizing gas (4 L min^{-1}); the interface temperature was 180 °C. Mass spectra were recorded on an MS-Kratos instrument (EI, 70 eV). The course of the reactions was monitored and the purity of the products was checked by TLC on Silufol UV-254 plates. Dry DMF was used; other solvents were not dried. Compounds **3** (see Refs 6, 7) and **13**—**15** (see Refs 8, 11) were prepared as described earlier.

Synthesis of compounds 5—10 (general procedure). An appropriate thiol (1 mmol) and Et_3N (0.1 g, 1 mmol) were added to a solution of 8-chloro-5,7-dinitroquinoline (**4**) (0.25 g, 1 mmol) in dimethoxyethane (50 mL). The reaction mixture was stirred at room temperature for 0.5—2 h until the starting compound was completely consumed (monitoring by TLC) and poured into a 1 : 1 mixture of water and HCl (250 mL). The precipitate that formed was filtered off, washed with water to a neutral reaction, and dried in air. Oily products were extracted with ethyl acetate (2×50 mL), and the extracts were dried with Na_2SO_4 and concentrated.

5,7-Dinitro-8-(phenylthio)quinoline (5). Yield 0.29 g (88%), orange crystals, m.p. 153—155 °C. Found (%): C, 55.23; H, 2.91; N, 12.67; S, 9.93. $C_{15}H_9N_3O_4S$. Calculated (%): C, 55.04; H, 2.77; N, 12.84; S, 9.80. ^{1}H NMR (DMSO-d_6), δ: 7.27—7.44 (m, 5 H, Ph); 7.96 (dd, 1 H, J_1 = 8.7 Hz, J_2 = 3.9 Hz); 8.88 (s, 1 H); 8.95 (d, 1 H, J = 8.7 Hz); 9.10 (d, 1 H, J_1 = 3.7 Hz). ^{13}C NMR (DMSO-d_6), δ: 120.16, 121.61, 126.48, 128.19, 129.36, 130.79, 132.64, 132.78, 138.52, 144.08, 145.90, 148.48, 152.66.

8-Benzylthio-5,7-dinitroquinoline (6). Yield 0.29 g (86%), yellow crystals, m.p. 132—134 °C. Found (%): C, 56.23; H, 3.14; N, 12.47; S, 9.48. $C_{16}H_{11}N_3O_4S$. Calculated (%): C, 56.30; H, 3.25; N, 12.31; S, 9.39. ^{1}H NMR (DMSO-d_6), δ: 4.65 (s, 2 H, CH_2); 6.98—7.35 (m, 5 H, Ph); 8.02 (dd, 1 H, J_1 = 8.9 Hz, J_2 = 4.1 Hz); 8.82 (s, 1 H); 8.95 (d, 1 H, J = 8.7 Hz); 9.33 (d, 1 H, J = 3.4 Hz). ^{13}C NMR (DMSO-d_6), δ: 40.22, 118.70, 121.56, 126.20, 127.41, 128.40, 128.79, 132.93, 136.90, 138.69, 144.13, 146.60, 149.92, 152.62.

8-Furfurylthio-5,7-dinitroquinoline (7). Yield 0.25 g (74%), yellow-green crystals, m.p. 111—113 °C. Found (%): C, 50.68; H, 2.65; N, 12.61; S, 9.43. $C_{14}H_9N_3O_5S$. Calculated (%): C, 50.75; H, 2.74; N, 12.68; S, 9.68. ^{1}H NMR (DMSO-d_6), δ: 4.75 (s, 2 H, CH_2); 5.86 (s, 1 H); 6.20 (s, 1 H); 7.44 (s, 1 H); 8.03 (dd, 1 H, J_1 = 8.8 Hz, J_2 = 4.0 Hz); 8.86 (s, 1 H); 8.97 (d, 1 H, J = 8.6 Hz); 9.32 (d, 1 H, J = 3.3 Hz). ^{13}C NMR (DMSO-d_6), δ: 32.68, 108.51, 110.52, 118.62, 121.61, 126.18, 133.00, 137.77, 143.09, 144.49, 146.56, 149.92, 150.39, 152.73.

8-Cyclohexylthio-5,7-dinitroquinoline (8). Yield 0.28 g (83%), yellow crystals, m.p. 138—140 °C. Found (%): C, 54.12; H, 4.58; N, 12.69; S, 9.73. $C_{15}H_{15}N_3O_4S$. Calculated (%): C, 54.04; H, 4.54; N, 12.60; S, 9.62. ^{1}H NMR (DMSO-d_6), δ: 1.08—1.80 (m, 10 H); 3.99—4.37 (m, 1 H, CH); 8.00 (dd, 1 H, J_1 = 8.8 Hz, J_2 = 4.0 Hz); 8.92—8.97 (m, 2 H); 9.28 (d, 1 H, J = 3.2 Hz).

^{13}C NMR (DMSO-d_6), δ: 24.91, 25.04, 41.91, 118.39, 121.43, 126.04, 132.99, 136.39, 144.72, 146.92, 151.28, 152.82.

8-(4-Chlorophenylthio)-5,7-dinitroquinoline (9). Yield 0.21 g (58%), orange crystals, m.p. 150—152 °C (EtOH). Found (%): C, 49.67; H, 2.41; N, 11.67; S, 8.93. $C_{15}H_8ClN_3O_4S$. Calculated (%): C, 49.80; H, 2.23; N, 11.62; S, 8.86. ^{1}H NMR (DMSO-d_6), δ: 7.35 (s, 4 H, Ph); 7.96 (dd, 1 H, J_1 = 8.8 Hz, J_2 = 4.0 Hz); 8.86—9.02 (m, 2 H); 9.09 (d, 1 H, J = 2.7 Hz). ^{13}C NMR (DMSO-d_6), δ: 120.01, 121.75, 126.51, 129.26, 132.08, 132.41, 132.81, 137.74, 144.40, 145.78, 148.71, 152.72.

Methyl 2-[(5,7-dinitroquinolin-8-yl)sulfanyl]acetate (10). Yield 0.2 g (63%), yellow crystals, m.p. 110—113 °C. Found (%): C, 44.42; H, 2.93; N, 12.87; S, 9.93. $C_{12}H_9N_3O_6S$. Calculated (%): C, 44.58; H, 2.81; N, 13.00; S, 9.92. ^{1}H NMR (DMSO-d_6), δ: 3.55 (s, 3 H, Me); 4.29 (s, 2 H, CH_2); 8.00 (dd, 1 H, J_1 = 8.6 Hz, J_2 = 3.7 Hz); 8.85—9.04 (m, 2 H); 9.17 (d, 1 H, J = 2.8 Hz). ^{13}C NMR (DMSO-d_6), δ: 52.25, 138.99, 139.58, 143.92, 144.10, 146.17, 149.29, 152.12, 169.13, 169.88.

5,7-Dinitro-8-phenoxyquinoline (11). Phenol (0.372 g, 4 mmol) and Na_2CO_3 (0.42 g, 4 mmol) were added to a solution of dinitroquinoline **4** (1 g, 4 mmol) in acetonitrile (50 mL). The reaction mixture was refluxed for 2 h until the starting compound was completely consumed (monitoring by TLC), poured into a five-fold excess of water, and acidified with HCl to pH 1—2. The precipitate that formed was filtered off and washed with water to a neutral reaction. Yield 1.1 g (89%), white crystals, m.p. 127—130 °C. Found (%): C, 57.94; H, 2.96; N, 13.46. $C_{15}H_9N_3O_5$. Calculated (%): C, 57.88; H, 2.91; N, 13.50. ^{1}H NMR (DMSO-d_6), δ: 6.93—7.35 (m, 5 H, Ph); 7.96 (dd, 1 H, J_1 = 8.6 Hz, J_2 = 3.7 Hz); 8.84—9.10 (m, 3 H). ^{13}C NMR (DMSO-d_6), δ: 115.72, 120.66, 122.96, 124.37, 126.71, 129.71, 132.58, 137.42, 140.47, 141.59, 141.79, 148.55, 153.03, 158.78.

8-Methoxy-5,7-dinitroquinoline (12). A 2 *M* solution of MeONa (4 mmol) in MeOH (2 mL) was added to a solution of dinitroquinoline **4** (0.5 g, 2 mmol) in methanol (30 mL). The reaction mixture was refluxed for 1.5 h until the starting compound was completely consumed (monitoring by TLC), poured into a five-fold excess of water, and acidified with HCl to pH 2. The precipitate that formed was filtered off and washed with water to a neutral reaction. Yield 0.5 g (99%), white crystals, m.p. 149—151 °C. Found (%): C, 48.24; H, 2.71; N, 16.81. $C_{10}H_7N_3O_5$. Calculated (%): C, 48.20; H, 2.83; N, 16.68. ^{1}H NMR (DMSO-d_6), δ: 4.42 (s, 3 H, CH_3); 8.00 (dd, 1 H, J_1 = 8.6 Hz, J_2 = 3.7 Hz); 8.83—9.06 (m, 2 H); 9.18 (d, 1 H, J = 2.7 Hz). ^{13}C NMR (DMSO-d_6), δ: 64.96, 120.61, 123.92, 126.36, 132.55, 139.28, 141.74, 151.80, 154.4.

8-[(4-Chlorophenyl)amino]-5,7-dinitroquinoline (16). 4-Chloroaniline (0.25 g, 2 mmol) was added to a solution of quinoline **4** (0.25 g, 1 mmol) in ethanol (50 mL). The reaction mixture was stirred at room temperature for 2.5 h (monitoring by TLC), poured into a five-fold excess of water, and acidified with HCl to pH 1—2. The precipitate that formed was filtered off and washed with water to a neutral reaction. Yield 0.28 g (80%), orange crystals, m.p. 172—174 °C. Found (%): C, 52.37; H, 2.71; N, 16.12. $C_{15}H_9ClN_4O_4$. Calculated (%): C, 52.26; H, 2.63; N, 16.25. ^{1}H NMR (DMSO-d_6), δ: 7.16—7.48 (m, 4 H, C_6H_4); 8.01 (dd, 1 H, J_1 = 8.6 Hz, J_2 = 2.8 Hz); 8.9 (s, 1 H); 9.07 (d, 1 H, J = 2.7 Hz); 9.18 (d, 1 H, J = 8.6 Hz); 10.85 (s, 1 H, NH). ^{13}C NMR (DMSO-d_6), δ: 122.46, 125.22, 127.17, 128.86, 129.28, 132.72, 133.12, 138.82, 139.92, 141.24, 149.73.

Synthesis of compounds 17—22 and 24—29 (general procedure). A mixture of an appropriate 8-R-5,7-dinitroquinoline (1 mmol), paraformaldehyde (1 mmol), and sarcosine (1 mmol) was refluxed in toluene (30 mL), while adding paraformaldehyde (1 mmol) and sarcosine (1 mmol) every hour until the starting compound was completely consumed. After the reaction was completed, the reaction mixture was cooled and concentrated *in vacuo*. The residue was separated by column chromatography on SiO_2 with $CHCl_3$ or $CHCl_3$—MeOH (10 : 1) as eluents.

2-Methyl-4-nitro-5-phenylthio-2,3-dihydro-1*H*-pyrrolo-[3,4-*f*]quinoline (17). Yield 0.12 g (35%), yellow crystals, m.p. 182—185 °C (THF). Found (%): C, 64.13; H, 4.56; N, 12.61; S, 9.43. $C_{18}H_{15}N_3O_2S$. Calculated (%): C, 64.08; H, 4.48; N, 12.45; S, 9.50. ^{1}H NMR ($CDCl_3$), δ: 2.70 (s, 3 H, Me); 4.20 (s, 2 H, CH_2); 4.40 (s, 2 H, CH_2); 6.99—7.23 (m, 5 H, Ph); 7.30—7.70 (dd, 1 H, J_1 = 8.0 Hz, J_2 = 3.9 Hz); 8.05 (d, 1 H, J = 8.6 Hz); 9.03 (d, 1 H, J = 3.3 Hz). ^{13}C NMR ($CDCl_3$), δ: 59.73, 59.84, 123.07, 124.79, 126.62, 128.64, 129.66, 131.04, 132.68, 135.30, 141.01, 151.69.

5-Benzylthio-2-methyl-4-nitro-2,3-dihydro-1*H*-pyrrolo[3,4-*f*]-quinoline (18). Yield 0.23 g (65%), red crystals, m.p. 134—138 °C. Found (%): C, 64.91; H, 4.77; N, 12.03; S, 9.17. $C_{19}H_{17}N_3O_2S$. Calculated (%): C, 64.94; H, 4.88; N, 11.96; S, 9.12. ^{1}H NMR ($CDCl_3$), δ: 2.66 (s, 3 H, Me); 4.11 (s, 2 H, CH_2); 4.33 (s, 2 H, CH_2); 4.38 (s, 2 H, CH_2); 7.01—7.17 (m, 5 H, Ph); 7.57 (dd, 1 H, J_1 = 8.2 Hz, J_2 = 4.2 Hz); 8.06 (d, 1 H, J = 8.2 Hz); 9.12—9.18 (m, 1 H). ^{13}C NMR ($CDCl_3$), δ: 40.75, 42.09, 59.69, 59.77, 122.90, 124.64, 126.78, 127.12, 128.20, 128.83, 130.62, 133.04, 137.13, 140.37, 147.61, 151.27.

5-Cyclohexylthio-2-methyl-4-nitro-2,3-dihydro-1*H*-pyrro-lo[3,4-*f*]quinoline (19). Yield 0.2 g (58%), yellow crystals, m.p. 189—192 °C. Found (%): C, 62.87; H, 6.31; N, 12.11; S, 9.33. $C_{18}H_{21}N_3O_2S$. Calculated (%): C, 62.95; H, 6.16; N, 12.23; S, 9.34. ^{1}H NMR ($CDCl_3$), δ: 1.00—1.89 (m, 10 H); 2.67 (s, 3 H, Me); 3.61—3.83 (m, 1 H, CH); 4.14 (s, 2 H, CH_2); 4.35 (s, 2 H, CH_2); 7.55 (dd, 1 H, J_1 = 8.3 Hz, J_2 = 4.2 Hz); 8.05 (d, 1 H, J = 7.3 Hz); 9.11 (d, 1 H, J = 2.4 Hz). ^{13}C NMR ($CDCl_3$), δ: 25.42, 25.67, 33.05, 42.09, 47.65, 59.58, 59.70, 122.77, 124.43, 126.11, 130.25, 132.91, 140.11, 147.82, 150.70, 151.23.

5-Furfurylthio-2-methyl-4-nitro-2,3-dihydro-1*H*-pyrrolo-[3,4-*f*]quinoline (20). Yield 0.15 g (43%), yellow-brown crystals, m.p. 180—182 °C (THF). Found (%): C, 59.68; H, 4.56; N, 12.51; S, 9.23. $C_{17}H_{15}N_3O_3S$. Calculated (%): C, 59.81; H, 4.43; N, 12.31; S, 9.39. ^{1}H NMR ($CDCl_3$), δ: 2.68 (s, 3 H, Me); 4.14 (s, 2 H, CH_2); 4.29—4.48 (m, 4 H, 2 CH_2); 5.68 (s, 1 H); 6.07 (s, 1 H); 7.19 (s, 1 H); 7.57 (dd, 1 H, J_1 = 8.0 Hz, J_2 = 3.6 Hz); 8.07 (d, 1 H, J = 8.0 Hz); 9.13 (d, 1 H, J = 3.5 Hz). ^{13}C NMR ($CDCl_3$), δ: 32.79, 42.01, 59.62, 59.71, 107.77, 110.08, 122.85, 124.59, 126.16, 130.55, 133.03, 140.52, 142.11, 143.89, 147.41, 150.28, 151.27.

5-[(4-Chlorophenyl)thio]-2-methyl-4-nitro-2,3-dihydro-1*H*-pyrrolo[3,4-*f*]quinoline (21a). Yield 0.11 g (30%), yellow crystals, m.p. 196—198 °C (EtOH). Found (%): C, 58.19; H, 3.88; N, 11.45; S, 8.71. $C_{18}H_{14}ClN_3O_2S$. Calculated (%): C, 58.14; H, 3.79; N, 11.30; S, 8.62. ^{1}H NMR ($CDCl_3$), δ: 2.71 (s, 3 H, Me); 4.21 (s, 2 H, CH_2); 4.41 (s, 2 H, CH_2); 7.10—7.25 (m, 4 H, C_6H_4); 7.56 (dd, 1 H, J_1 = 8.3 Hz, J_2 = 4.2 Hz); 8.08 (dd, 1 H, J_1 = 8.3 Hz, J_2 = 1.4 Hz); 9.04 (dd, 1 H, J_1 = 4.2 Hz, J_2 = 1.4 Hz).

Methyl 2-[(2-methyl-4-nitro-2,3-dihydro-1*H*-pyrrolo[3,4-*f*]-quinolin-5-yl)sulfanyl]acetate (21b). Yield 0.09 g (27%), yellow crystals, m.p. 135—139 °C. Found (%): C, 54.08; H, 4.48;

N, 12.69; S, 9.43. $C_{15}H_{15}N_3O_4S$. Calculated (%): C, 54.04; H, 4.54; N, 12.60; S, 9.62. ^{1}H NMR ($CDCl_3$), δ: 2.71 (s, 3 H, Me); 3.63 (s, 3 H, CH_3); 3.96 (s, 2 H, CH_2); 4.22 (s, 2 H, CH_2); 4.38 (s, 2 H, CH_2); 7.6 (dd, 1 H, J_1 = 8.3 Hz, J_2 = 4.2 Hz); 8.11 (dd, 1 H, J_1 = 8.7 Hz, J_2 = 1.7 Hz); 9.09—9.15 (m, 1 H). ^{13}C NMR ($CDCl_3$), δ: 37.55, 42.32, 52.49, 59.97, 60.17, 123.24, 125.06, 125.99, 131.17, 133.42, 141.24, 147.31, 150.31, 151.47, 169.71. MS, *m/z*: 334 $[M]^+$.

5-[(4-Chlorophenyl)thio]-2-methyl-4-nitro-2*H*-pyrrolo[3,4-*f*]-quinoline (22a). Yield 0.026 g (7%), red crystals, m.p. 240—243 °C (EtOH). Found (%): C, 58.42; H, 3.34; N, 11.45; S, 8.54. $C_{18}H_{12}ClN_3O_2S$. Calculated (%): C, 58.46; H, 3.27; N, 11.36; S, 8.67. ^{1}H NMR ($CDCl_3$), δ: 4.07 (s, 3 H, Me); 7.08—7.25 (m, 5 H); 7.41—7.52 (m, 1 H); 7.60 (s, 1 H, CH); 8.35 (d, 1 H, J = 7.6 Hz); 8.76—8.85 (m, 1 H).

Methyl 2-[(2-methyl-4-nitro-2*H*-pyrrolo[3,4-*f*]quinolin-5-yl)sulfanyl]acetate (22b). Yield 0.05 g (15%), red crystals, m.p. 198—202 °C (THF). Found (%): C, 54.46; H, 3.87; N, 12.61; S, 9.74. $C_{15}H_{13}N_3O_4S$. Calculated (%): C, 54.37; H, 3.95; N, 12.68; S, 9.68. ^{1}H NMR ($CDCl_3$), δ: 3.64 (s, 3 H, Me); 3.9 (s, 2 H, CH_2); 4.04 (s, 3 H, CH_3); 7.23 (d, 1 H, J = 1.0 Hz); 7.46—7.54 (m, 1 H); 7.57 (d, 1 H, J = 2.1 Hz); 8.36 (dd, 1 H, J_1 = 8 Hz, J_2 = 1.7 Hz); 8.91 (dd, 1 H, J_1 = 4.2 Hz, J_2 = 1.4 Hz). MS, *m/z*: 331 $[M]^+$.

5-Dimethylamino-2-methyl-4-nitro-2,3-dihydro-1*H*-pyrrolo-[3,4-*f*]quinoline (24). Yield 0.12 g (43%), red crystals, m.p. 122—125 °C. Found (%): C, 61.83; H, 5.87; N, 20.57. $C_{14}H_{16}N_4O_2$. Calculated (%): C, 61.75; H, 5.92; N, 20.58. ^{1}H NMR ($CDCl_3$), δ: 2.68 (s, 3 H, Me); 3.16 (s, 6 H, NMe_2); 4.22 (s, 2 H, CH_2); 4.28 (s, 2 H, CH_2); 7.50 (dd, 1 H, J_1 = 8.3 Hz, J_2 = 4.0 Hz); 7.96 (dd, 1 H, J_1 = 8.3 Hz, J_2 = 1.7 Hz); 8.96 (d, 1 H, J_1 = 4.0 Hz). HRMS: found *m/z* 273.1351; $C_{14}H_{17}N_4O_2$; calculated 273.1346.

2-Methyl-4-nitro-5-piperidino-2,3-dihydro-1*H*-pyrrolo[3,4-*f*]-quinoline (25). ^{1}H NMR ($CDCl_3$), δ: 1.56—1.89 (m, 6 H); 2.60 (s, 3 H, NMe); 3.22—3.41 (m, 4 H); 4.08—4.23 (m, 4 H); 7.34—7.46 (m, 1 H); 7.81—7.91 (m, 1 H); 8.82—8.90 (m, 1 H). HRMS: found *m/z* 313.1662; $C_{17}H_{21}N_4O_2$; calculated 313.1659.

2-Methyl-5-morpholino-4-nitro-2,3-dihydro-1*H*-pyrrolo-[3,4-*f*]quinoline (26). ^{1}H NMR ($CDCl_3$), δ: 2.67 (s, 3 H, Me); 3.48 (t, 4 H, J = 4.5 Hz); 3.88 (t, 4 H, J = 4.5 Hz); 4.20 (s, 2 H, CH_2); 4.30 (s, 2 H, CH_2); 7.45—7.51 (m, 1 H); 7.93—8.02 (m, 1 H); 8.92—8.95 (m, 1 H). HRMS: found *m/z* 315.1453; $C_{16}H_{18}N_4O_3$; calculated 315.1452.

5-[(4-Chlorophenyl)amino]-2-methyl-4,9b-dinitro-2,3,3*a*,9*b*-tetrahydro-1*H*-pyrrolo[3,4-*f*]quinoline (27). Yield 0.24 g (59%), orange crystals, m.p. 183—186 °C. Found (%): C, 53.72; H, 4.12; N, 17.40. $C_{18}H_{16}ClN_5O_4$. Calculated (%): C, 53.81; H, 4.01; N, 17.43. ^{1}H NMR ($CDCl_3$), δ: 2.4 (s, 3 H, Me); 2.48 (t, 1 H, J = 9.0 Hz); 3.13 (d, 1 H, J = 8.7 Hz); 3.71 (t, 1 H, J = 8.7 Hz); 4.18 (d, 1 H, J = 11.1 Hz); 4.78 (t, 1 H, J = 8.2 Hz); 6.88 (d, 2 H, C_6H_4, J = 8.7 Hz); 7.24—7.34 (m, 2 H, C_6H_4); 7.53 (dd, 1 H, J_1 = 8 Hz, J_2 = 4.5 Hz); 8.02 (d, 1 H, J = 8.0 Hz); 8.64 (d, 1 H, J = 4.5 Hz); 10.26 (s, 1 H, NH). ^{13}C NMR ($CDCl_3$), δ: 41.45, 43.74, 63.05, 67.41, 92.41, 122.61, 123.23, 126.38, 128.95, 129.04, 130.49, 136.37, 138.51, 138.69, 145.39, 150.18. MS, *m/z*: 401 $[M]^+$.

5-[(4-Chlorophenyl)amino]-2-methyl-4-nitro-2,3-dihydro-1*H*-pyrrolo[3,4-*f*]quinoline (28). Yield 0.24 g (67%), red crystals, m.p. 192—195 °C. Found (%): C, 60.83; H, 4.00; N, 15.72. $C_{18}H_{15}ClN_4O_2$. Calculated (%): C, 60.94; H, 4.26; N, 15.79. ^{1}H NMR ($CDCl_3$), δ: 2.97 (s, 3 H, Me); 4.29 (s, 2 H); 4.38 (s, 2 H); 6.96 (d, 2 H, C_6H_4, J = 8.7 Hz); 7.16—7.35 (m, 2 H, C_6H_4); 7.6 (dd, 1 H, J_1 = 8.3 Hz, J_2 = 4.2 Hz); 8.01 (dd, 1 H, J_1 = 8.3 Hz, J_2 = 1.4 Hz); 8.83 (dd, 1 H, J_1 = 4.3 Hz, J_2 = 1.6 Hz); 9.06 (s, 1 H, NH). ^{13}C NMR ($CDCl_3$), δ: 42.49, 59.44, 62.80, 120.36, 124.37, 125.68, 126.97, 128.85, 129.01, 129.21, 132.72, 133.36, 135.04, 139.66, 140.66, 148.19. MS, *m/z*: 354 $[M]^+$.

5-[(4-Chlorophenyl)amino]-2-methyl-4-nitro-2*H*-pyrrolo-[3,4-*f*]quinoline (29). Yield 0.05 g (15%), red crystals, m.p. 211—215 °C. Found (%): C, 61.36; H, 3.86; N, 15.83. $C_{18}H_{13}N_4O_2$. Calculated (%): C, 61.28; H, 3.71; N, 15.88. ^{1}H NMR ($CDCl_3$), δ: 4.00 (s, 3 H, Me); 6.98 (d, 2 H, J = 7.6 Hz); 7.24—7.35 (m, 2 H); 7.46—7.65 (m, 3 H); 8.31 (d, 1 H, J = 8.0 Hz); 8.65 (d, 1 H, J = 4.5 Hz); 9.84 (s, NH). ^{13}C NMR ($CDCl_3$), δ: 41.45, 43.73, 63.05, 67.41, 92.40, 122.61, 123.23, 126.37, 128.95, 129.04, 130.49, 136.36, 138.51, 138.69, 145.38, 150.18. MS, *m/z*: 352 $[M]^+$.

X-ray diffraction studies of compounds **18** and **24** were carried out on Bruker SMART 1000 CCD and Bruker Apex II diffractometers, respectively (Mo-Kα radiation, graphite monochromator, ω scan mode). The structures were solved by the direct methods and refined anisotropically on F^2_{hkl} by the full-matrix least-squares method. The hydrogen atoms were located geometrically; their coordinates and thermal parameters were refined using a riding model with fixed idealized C—H bond lengths. Crystallographic parameters and the data collection and refinement statistics are summarized in Table 4. All cal-

Table 4. Crystallographic parameters and the data collection and refinement statistics for structures **18** and **24**

Parameter	**18**	**24**
Molecular formula	$C_{19}H_{17}N_3O_2S$	$C_{14}H_{16}N_4O_2$
Molecular weight	351.42	272.31
T/K	120	100
Crystal system	Triclinic	Triclinic
Space group	$P\bar{1}$	$P\bar{1}$
*Z*2	2	
a/Å	8.038(1)	8.0409(4)
b/Å	8.913(1)	9.3294(5)
c/Å	12.782(2)	9.8592(5)
α/deg	79.822(2)	103.495(1)
β/deg	78.543(2)	113.479(1)
γ/deg	67.736(2)	96.054(1)
V/Å^3	825.3(2)	643.11(6)
d_{calc}/g cm^{-3}	1.414	1.406
μ/cm^{-1}	2.14	0.98
F(000)	368	288
$2\theta_{max}$/deg	56	60
Number of measured /unique reflections	8494/3974	8353/3721
Number of reflections with $I > 2\sigma(I)$	2468	3264
Number of parameters refined	227	184
R_1	0.0479	0.0372
wR_2	0.0933	0.0856
GOOF	1.059	1.031
Residual electron density, e Å^{-3}(d_{max}/d_{min})	0.321/–0.344	0.416/–0.241

culations were performed with the SHELX program package (version 2009-9.1).[15]

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