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PREPARATION AND PROPERTIES OF NITROGEN DERIVATIVES OF BENZANTHRONE WITH HETEROCYCLIC FRAGMENTS

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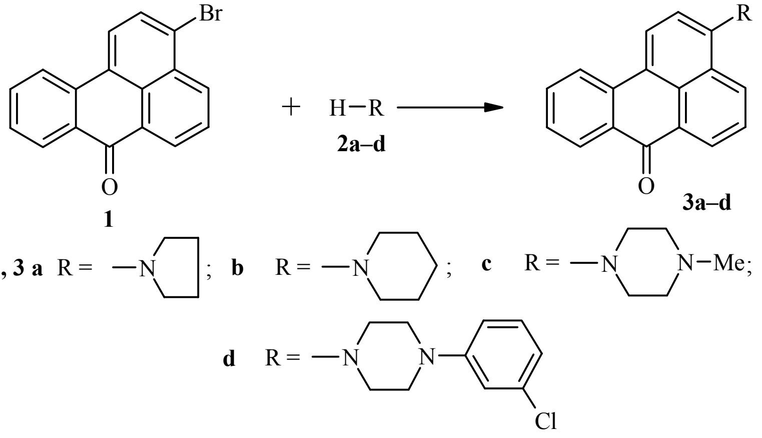
The preparation of new nitrogen derivatives of benzanthrone is described. X-ray diffraction structural data are given for 3-N-pyrrolidinobenzanthrone.

Keywords: benzanthrone, fluorescent probes, X-ray diffraction structural analysis.

We have synthesized and studied new fluorescent benzanthrone derivatives. These compounds have pronounced luminescence properties and, thus, have found use as luminescent dyes [1] and, recently, as fluorescent probes in biochemistry and medicine due to the sensitivity of their luminescence toward external factors [2].



In order to obtain new fluorescent compounds, we carried out nucleophilic substitution of the bromine atom in 3-bromobenzanthrone (**1**) with several nitrogen heterocyclic compounds **2a-d** by heating a mixing of reagents **1** and **2a-c** or **2d** at reflux. The products were separated by precipitation upon the addition of aqueous ethanol with subsequent purification by column chromatography. The IR, UV, and ^{1}H NMR spectral data as well as the elemental analyses support the proposed composition and structure of the products.

The UV spectra of **3a-d** show absorption bands characteristic for condensed aromatic compounds with λ_{max} 260-280 and 430-510 nm.

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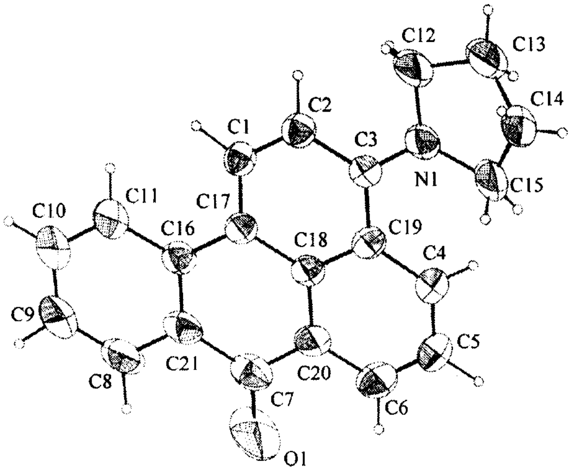

Fig. 1. Structure of **3a**.

The IR spectra of **3a-d** show bands at 3080-3020 (aromatic ring CH), 2960-2810 (aliphatic CH), 1630-1650 (C=O), and 1570-1590 cm^{-1} (condensed aromatic ring C=C).

The ^{1}H NMR spectra of the products display a multiplet for the aromatic protons at 7.80-9.10 ppm. The heterocyclic protons give suitable signals.

We studied the luminescence properties of these benzanthrone derivatives. The data permit us to consider **3a-d** as promising organic luminophors with high luminescence intensity, which display a large bathochromic shift dependent on the solvent polarity. The wavelengths of the luminescence maxima for **3a-d** in various solvents have been presented in our previous work [3].

An X-ray diffraction structural analysis was carried out for benzanthrone **3a**. Figure 1 gives the numbering scheme for the atoms and the thermal vibration ellipsoids in **3a**.

The analysis showed that the benzanthrone residue is planar, while the pyrrolidine residue has envelope conformation with a planar $N_{(1)}$–$C_{(15)}$–$C_{(13)}$–$C_{(12)}$ fragment. The quaternary $C_{(14)}$ atom extrudes from the envelope plane by 0.551(4) Å. The angle between the benzanthrone residue and $N_{(1)}$–$C_{(15)}$–$C_{(13)}$–$C_{(12)}$ plane is 151.4(1)°. The $N_{(1)}$–$C_{(3)}$ bond is shorter than the standard value (1.394 Å [4]) due to delocalization of the nitrogen electron pair in the benzanthrone π-system. The other bond lengths are close to the standard values (see Table 1). Table 2 gives some bond angles in **3a**.

TABLE 1. Bond Lengths in **3a**

Bond	*d*, Å	Bond	*d*, Å	Bond	*d*, Å
$C_{(1)}$–$C_{(2)}$	1.373(4)	$C_{(7)}$–$C_{(20)}$	1.459(4)	$C_{(13)}$–$C_{(14)}$	1.501(5)
$C_{(1)}$–$C_{(17)}$	1.381(4)	$C_{(7)}$–$O_{(1)}$	1.233(4)	$C_{(14)}$–$C_{(15)}$	1.519(4)
$C_{(2)}$–$C_{(3)}$	1.405(4)	$C_{(8)}$–$C_{(9)}$	1.373(5)	$C_{(15)}$–$N_{(1)}$	1.472(4)
$C_{(3)}$–$N_{(1)}$	1.374(3)	$C_{(8)}$–$C_{(21)}$	1.393(4)	$C_{(16)}$–$C_{(17)}$	1.448(6)
$C_{(3)}$–$C_{(19)}$	1.446(4)	$C_{(9)}$–$C_{(10)}$	1.388(5)	$C_{(16)}$–$C_{(21)}$	1.412(4)
$C_{(4)}$–$C_{(5)}$	1.371(4)	$C_{(10)}$–$C_{(11)}$	1.359(4)	$C_{(17)}$–$C_{(18)}$	1.429(3)
$C_{(4)}$–$C_{(19)}$	1.424(4)	$C_{(11)}$–$C_{(16)}$	1.420(4)	$C_{(18)}$–$C_{(19)}$	1.423(4)
$C_{(5)}$–$C_{(6)}$	1.368(4)	$C_{(12)}$–$N_{(1)}$	1.469(4)	$C_{(18)}$–$C_{(20)}$	1.424(4)
$C_{(6)}$–$C_{(20)}$	1.392(4)	$C_{(12)}$–$C_{(13)}$	1.516(4)		

TABLE 2. Bond Angles in **3a**

Angle	ω, deg.	Angle	ω, deg.
$C_{(1)}-C_{(17)}-C_{(16)}$	123.3(5)	$C_{(14)}-C_{(13)}-C_{(12)}$	101.8(4)
$C_{(1)}-C_{(17)}-C_{(18)}$	116.4(8)	$C_{(15)}-C_{(14)}-C_{(13)}$	103.1(1)
$C_{(2)}-C_{(1)}-C_{(17)}$	124.0(5)	$C_{(16)}-C_{(21)}-C_{(8)}$	121.0(1)
$C_{(3)}-C_{(2)}-C_{(1)}$	121.4(7)	$C_{(17)}-C_{(16)}-C_{(11)}$	123.4(2)
$C_{(3)}-C_{(19)}-C_{(4)}$	122.5(7)	$C_{(17)}-C_{(16)}-C_{(21)}$	121.1(3)
$C_{(3)}-C_{(19)}-C_{(18)}$	119.8(6)	$C_{(17)}-C_{(18)}-C_{(19)}$	120.9(6)
$C_{(3)}-N_{(1)}-C_{(12)}$	120.0(6)	$C_{(17)}-C_{(18)}-C_{(20)}$	119.6(1)
$C_{(3)}-N_{(1)}-C_{(15)}$	126.2(0)	$C_{(18)}-C_{(17)}-C_{(16)}$	120.1(7)
$C_{(4)}-C_{(5)}-C_{(6)}$	120.6(4)	$C_{(18)}-C_{(20)}-C_{(6)}$	119.7(8)
$C_{(4)}-C_{(19)}-C_{(18)}$	117.5(4)	$C_{(19)}-C_{(3)}-C_{(2)}$	116.6(8)
$C_{(5)}-C_{(6)}-C_{(20)}$	120.8(7)	$C_{(19)}-C_{(4)}-C_{(5)}$	121.5(5)
$C_{(7)}-C_{(20)}-C_{(6)}$	118.6(3)	$C_{(20)}-C_{(7)}-C_{(21)}$	117.7(2)
$C_{(7)}-C_{(20)}-C_{(18)}$	121.5(9)	$C_{(20)}-C_{(18)}-C_{(19)}$	119.3(8)
$C_{(7)}-C_{(21)}-C_{(8)}$	119.3(1)	$C_{(21)}-C_{(8)}-C_{(9)}$	121.3(8)
$C_{(7)}-C_{(21)}-C_{(16)}$	119.6(8)	$N_{(1)}-C_{(3)}-C_{(2)}$	119.5(8)
$C_{(8)}-C_{(9)}-C_{(10)}$	118.6(9)	$N_{(1)}-C_{(3)}-C_{(19)}$	123.6(9)
$C_{(9)}-C_{(10)}-C_{(11)}$	120.6(6)	$N_{(1)}-C_{(12)}-C_{(13)}$	109.9(1)
$C_{(10)}-C_{(11)}-C_{(16)}$	122.7(4)	$N_{(1)}-C_{(15)}-C_{(14)}$	103.6(1)
$C_{(11)}-C_{(16)}-C_{(21)}$	115.4(4)	$O_{(1)}-C_{(7)}-C_{(20)}$	122.2(3)
$C_{(13)}-C_{(12)}-N_{(1)}$	103.5(2)	$O_{(1)}-C_{(7)}-C_{(21)}$	120.0(1)

TABLE 3. Physical Characteristics of Compounds **3a-d**

Compound	Empirical formula	Found, % / Calculated, %				mp, °C	Yield, %
		C	H	N	Cl		
3a	$C_{21}H_{17}NO$	$\frac{84.19}{84.25}$	$\frac{5.73}{5.72}$	$\frac{4.60}{4.68}$		114-115	69
3b	$C_{22}H_{19}NO$	$\frac{84.27}{84.31}$	$\frac{6.07}{6.11}$	$\frac{4.51}{4.46}$		165-166	46
3c	$C_{22}H_{20}N_2O$	$\frac{79.32}{80.16}$	$\frac{8.41}{8.53}$	$\frac{6.17}{6.14}$		180-181	50
3d	$C_{27}H_{21}ClN_2O$	$\frac{75.65}{76.32}$	$\frac{4.95}{4.93}$	$\frac{6.35}{6.52}$	$\frac{9.42}{9.25}$	247 (with dec.)	44

TABLE 4. Spectral Characteristics of Compounds **3a-d**

Compound	UV spectrum, λ_{max}, nm (log ε)	IR spectrum, ν, cm^{-1}	^{1}H NMR spectrum, δ, ppm
3a	282.8 (4.42); 510.2 (4.09)	1572 (C=C); 1634 (C=O); 2832, 2860, 2996 (C–H)	2.00 (4H, m, CH_2); 3.56 (4H, m, NCH_2); 6.78-8.76 (9H, m, CH arom.)
3b	277.2 (4.42); 457.9 (4.13)	1572 (C=C); 1644 (C=O); 2804, 2932 (C–H)	1.82 (6H, m, CH_2); 3.16 (4H, m, NCH_2); 7.13-8.75 (9H, m, CH arom.)
3c	271.7 (4.50); 437.1 (4.22)	1576 (C=C); 1642 (C=O); 2812, 2936, 3072 (C–H)	2.39 (3H, s, CH_3); 2.70 (4H, m, CH_2); 3.20 (4H, m, NCH_2); 7.48-8.73 (9H, m, CH arom.)
3d	263.7 (4.43); 437.1 (4.05)	1576, 1594 (C=C); 1644 (C=O); 2836, 2948 (C–H)	3.49 (8H, d, NCH_2); 6.93-8.97 (13H, m, CH arom.)

EXPERIMENTAL

The ^{1}H NMR spectra were taken on a Bruker WH-90DS spectrometer at 90 MHz in $CDCl_3$ with TMS as the internal standard. The IR spectra of the products were taken on a Specord M-80 spectrometer in KBr pellets. The UV spectra of 10^{-5} mol/l solutions of the products in chloroform were taken on a Specord UV-VIS spectrometer. The reaction course was monitored by thin-layer chromatography on Silufol UV-254 plates using 6:1 benzene–acetonitrile as the eluent.

The physical characteristics of the products are given in Tables 3 and 4.

The unit cell parameters of orthorhombic crystals of **3a** are as follows: a = 8.089(2), b = 15.032(4), c = 24.510(5) Å; V = 2980(2) Å^3; d_{calc} = 1.334(1) g/cm^3; F(000) = 1264; μ = 0.082 mm^{-1}, Z = 8, space group *Pbca*. The structure of **3a** was determined using 2460 independent reflections on an automatic Syntex $P2_1$ diffractometer with Mo$K\alpha$ radiation, graphite monochromator, and $\theta/2\theta$ scanning to $2\theta_{max}$ = 50°. The structure was solved using the direct method [5] (initial R factor 0.198) and refined by the full-matrix anisotropic method of least squares to R = 0.0617. The hydrogen atoms were found in the difference map using the program package given by Andrianov [6].

3-N-Pyrrolidinobenzanthrone (3a). A mixture of 3-bromobenzanthrone **1** (0.3 g, 0.001 mol) and pyrrolidine (10 ml, 0.12 mol) was heated at reflux for 8 h, cooled, and poured into 1:1 aqueous ethanol (10 ml). The precipitate was filtered off and dried. Chromatography on a 1.5×30 cm column packed with silica gel 40/100 gave 0.22 g (69%) of compound **3a** as dark red crystals.

3-N-Piperidinobenzanthrone (3b) was obtained as orange crystals from compound **1** (0.3 g, 0.001 mol) and piperidine (10 ml, 0.10 mol) analogously to **3a**.

3-N-(N'-Methyl)piperazinobenzanthrone (3c) was obtained as orange crystals from compound **1** (0.3 g, 0.001 mol) and N-methylpiperazine (10 ml, 0.10 mol) analogously to **3a**.

3-N-[N'-(3'-Chlorophenyl)piperazino]benzanthrone (3d). A mixture of compound **1** (0.3 g, 0.001 mol), N-(3-chlorophenyl)piperazine (3 ml, 0.04 mol), and triethylamine (3 ml, 0.02 mol) was heated at reflux for 5 h. After cooling, the product was filtered off and dried. Column chromatography analogous to the procedure for **3a** gave **3d** as orange crystals.

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