

I. V. Zuika, Yu. Yu. Popelis,  
A. P. Sturis, and M. A. Tsirule

UDC 543.422.25:547.831.78

The additivity of the effect of the increments of the substituents on the <sup>13</sup>C chemical shifts in polysubstituted quinolines is demonstrated. In the case of substitution in the pyridine part of quinoline (R = CH<sub>3</sub>, OCH<sub>3</sub>, SCH<sub>3</sub>) the ortho increments are depressed as compared with the increments in benzene derivatives. This is associated with a change in the charge on the ring carbon atom and polarization of the C-H bond because of steric hindrance.

In a continuation of our studies of the <sup>13</sup>C NMR spectra of quinoline derivatives [1-4] in the present research we examined the increments of the substituents and their additivity in 6-methyl, 6-chloro, 6-bromo, 6-methoxy, 3-bromo, 4-methyl, 4-methoxy, 4-methylthio, 2-methyl, 2,3-dimethyl, 2,4-dimethyl, 2,6-dimethyl, and 2,4,6-trimethyl derivatives of 8-mercaptoquinoline (Ia-XIIa) and 8-(methylthio)quinoline (Ib-XIIIb). The increments of the substituents were determined from the spectra of 6-methyl- [5], 6-chloro-, 6-bromo-, 6-methoxy- [5], 4-(methylthio)- [1], 2-methyl- [5], 2,3-dimethyl- [6], 2,4-dimethyl- [6], 3-methyl- [5], 8-mercapto- [2], and 8-(methylthio)quinolines (I-IV, VIII-XI, and XIV-XVI) [2]. The <sup>13</sup>C chemical shifts of quinoline (XVII) are presented in [1]. The assignment of the signals was made on the basis of the spectra without decoupling of the protons or with extraresonance suppression of spin-spin coupling. The <sup>13</sup>C chemical shifts and the increments of the substituents are presented in Tables 1 and 2. The contributions of the substituents to the <sup>13</sup>C chemical shifts of Ia-XIIIa and Ib-XIIIb are compared with the values

TABLE 1. <sup>13</sup>C Chemical Shifts (δ, ppm) of Quinoline Derivatives

Compound	C <sub>2</sub>	C <sub>3</sub>	C <sub>4</sub>	C <sub>5</sub>	C <sub>6</sub>	C <sub>7</sub>	C <sub>8</sub>	C <sub>9</sub>	C <sub>10</sub>	C-R
I	149,3	120,8	135,0	126,5	135,9	131,4	129,1	147,0	128,2	21,2 (6-CH <sub>3</sub> )
Ia	148,6	121,9	136,4	123,8	136,6	129,1	134,7	142,4	128,9	21,5 (6-CH <sub>3</sub> )
Ib	148,8	122,1	136,1	123,1	137,0	125,6	140,0	144,8	128,7	22,3 (6-CH <sub>3</sub> ); 14,8 (8-SCH <sub>3</sub> )
II	151,0	122,3	135,3	126,8	132,6	130,7	131,6	147,0	129,2	
IIa	149,6	122,8	136,2	123,2	132,3	127,3	137,9	142,2	129,1	
III	151,1	122,2	135,1	130,1	120,8	133,1	131,6	147,1	129,5	
IIIa	149,8	122,8	136,1	126,5	120,5	129,7	138,1	142,3	129,7	
IIIb	149,6	122,9	135,6	125,8	121,3	125,6	143,3	144,2	129,1	14,7 (8-SCH <sub>3</sub> )
IVa	147,0	122,3	136,0	102,7	157,7	119,7	136,9	140,2	130,0	56,2 (6-OCH <sub>3</sub> )
IVb	146,8	122,4	135,5	101,2	158,3	115,9	142,3	142,3	129,5	55,7 (6-OCH <sub>3</sub> ); 14,6 (8-SCH <sub>3</sub> )
Va	150,5	118,3	138,1	123,9	128,0	127,7	135,6	142,0	129,8	
Vb	150,3	118,4	137,8	123,0	128,2	123,6	141,1	144,0	129,5	14,7 (8-SCH <sub>3</sub> )
VIa	149,2	122,9	145,8	120,9	126,6	127,4	136,1	143,9	129,1	19,2 (4-CH <sub>3</sub> )
VIb	149,1	123,0	145,1	119,9	126,8	123,0	141,0	145,5	128,5	19,4 (4-CH <sub>3</sub> ); 14,8 (8-SCH <sub>3</sub> )
VIIa	150,0	101,0	164,0	118,5	126,3	128,8	136,5	144,8	122,2	56,6 (4-OCH <sub>3</sub> )
VIIb	150,7	101,3	163,0	118,1	126,2	123,8	140,0	146,6	121,7	56,3 (4-OCH <sub>3</sub> ); 14,9 (8-SCH <sub>3</sub> )
VIIIa	148,1	115,6	150,5	120,1	126,5	127,9	136,3	142,9	127,0	14,7 (4-SCH <sub>3</sub> )
VIIIb	148,4	115,9	149,6	119,5	126,7	123,6	141,3	144,3	125,3	14,8; 14,6 (4-SCH <sub>3</sub> , 8-SCH <sub>3</sub> )
IXa	158,4	122,7	137,2	124,4	126,0	127,1	134,7	143,1	127,1	25,7 (2-CH <sub>3</sub> )
IXb	158,3	122,9	136,6	123,6	126,2	123,0	139,6	145,3	126,7	25,7 (2-CH <sub>3</sub> ); 14,5 (8-SCH <sub>3</sub> )
Xa	158,2	130,9	136,2	123,6	125,9	126,1	134,4	141,6	127,9	23,8 (2-CH <sub>3</sub> ); 19,6 (3-CH <sub>3</sub> )
Xb	158,3	131,1	135,6	123,1	126,2	122,2	139,4	144,2	127,6	24,0 (2-CH <sub>3</sub> ); 19,8 (3-CH <sub>3</sub> ); 14,6 (8-SCH <sub>3</sub> )
XIa	157,4	123,4	146,6	119,9	125,8	127,6	136,3	142,6	127,1	25,2 (2-CH <sub>3</sub> ); 19,1 (4-CH <sub>3</sub> )
XIIa	157,4	122,6	136,6	123,5	135,6	129,1	134,2	141,9	127,1	25,6 (2-CH <sub>3</sub> ); 21,8 (6-CH <sub>3</sub> )
XIIb	157,5	123,0	136,1	123,0	135,9	125,3	139,2	144,2	126,7	25,8 (2-CH <sub>3</sub> ); 22,2 (6-CH <sub>3</sub> ); 14,8 (8-SCH <sub>3</sub> )
XIIIa	156,4	123,4	145,7	119,3	135,7	129,5	136,0	141,2	127,2	25,1 (2-CH <sub>3</sub> ); 22,2 (6-CH <sub>3</sub> ); 19,1 (4-CH <sub>3</sub> )
XIIIb	156,8	123,6	143,9	118,9	135,3	124,7	139,8	143,9	126,5	25,4 (2-CH <sub>3</sub> ); 22,4 (6-CH <sub>3</sub> ); 19,0 (4-CH <sub>3</sub> ); 14,7 (8-SCH <sub>3</sub> )

Institute of Inorganic Chemistry, Academy of Sciences of the Latvian SSR, Riga 226934.  
Translated from Khimiya Geterotsiklicheskikh Soedinenii, No. 7, pp. 937-940, July, 1981.  
Original article submitted February 12, 1980.

TABLE 2. Increments of the Substituents ( $\Delta\delta$ , ppm) in Mono-substituted Quinolines

Substituent (compound)	$\Delta\delta$ (C <sub>2</sub> )	$\Delta\delta$ (C <sub>3</sub> )	$\Delta\delta$ (C <sub>4</sub> )	$\Delta\delta$ (C <sub>5</sub> )	$\Delta\delta$ (C <sub>6</sub> )	$\Delta\delta$ (C <sub>7</sub> )	$\Delta\delta$ (C <sub>8</sub> )	$\Delta\delta$ (C <sub>9</sub> )	$\Delta\delta$ (C <sub>10</sub> )
6-CH <sub>3</sub> (I)	-1,4	-0,8	-1,4	-1,1	9,5	2,2	-0,3	-1,3	0
6-Cl (II)	0,3	0,7	-1,1	-1,6	5,6	0,8	1,7	-1,8	0,4
6-Br (III)	0,4	0,6	-1,3	1,7	-6,2	3,2	1,7	-1,7	0,7
6-OCH <sub>3</sub> (IV)	-1,9	-0,4	-1,9	-23,3	30,7	-7,8	0,9	-4,3	0,5
3-Br (V) <sup>a</sup>	0,8	-3,7	0,9	-1,0	1,1	0,3	0,2	-2,1	0,7
3-Br (V) <sup>b</sup>	0,9	-3,8	1,1	-0,9	1,0	0,4	0,5	-1,8	1,0
4-CH <sub>3</sub> (VI)	-0,4	0,7	8,2	-4,0	-0,3	-0,4	0,4	-0,5	-0,2
4-OCH <sub>3</sub> (VII) <sup>a</sup>	0,3	-21,0	26,8	-6,4	-0,6	1,4	1,1	0,7	-6,9
4-OCH <sub>3</sub> (VII) <sup>b</sup>	1,3	-20,9	26,3	-5,8	-1,0	0,6	-0,6	0,8	-6,8
4-SCH <sub>3</sub> (VIII)	-0,9	-6,5	11,2	-4,6	-0,5	0,1	0,5	0,2	-2,3
2-CH <sub>3</sub> (IX)	8,0	0,8	-0,1	-0,3	-1,0	-0,1	-0,7	-0,4	-1,8
3-CH <sub>3</sub> (XIV)	2,0	9,2	-1,4	-0,5	-0,1	-1,0	-0,2	-1,7	-0,1
8-SH (XV)	-1,0	0,4	0,8	-3,5	-0,1	-2,5	5,5	-4,7	0,3
8-SCH <sub>3</sub> (XVI)	-1,3	0,6	0,3	-4,5	0,2	-6,7	10,7	-3,0	-0,3

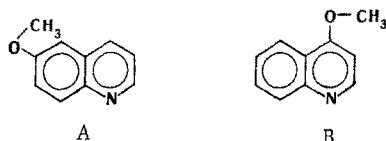
<sup>a</sup>Calculated from the increments of the SH group in XV. <sup>b</sup>Calculated from the increments of the SCH<sub>3</sub> group in XVI.

TABLE 3. Experimental (calculated) Changes in the <sup>13</sup>C Chemical Shifts ( $\Delta\delta$ , ppm) of Quinoline Derivatives Relative to Unsubstituted Quinoline

Compound	C <sub>2</sub>	C <sub>3</sub>	C <sub>4</sub>	C <sub>5</sub>	C <sub>6</sub>	C <sub>7</sub>	C <sub>8</sub>	C <sub>9</sub>	C <sub>10</sub>
Ia	-2,1 (-2,4)	0,3 (-0,4)	0 (-0,6)	-4,6 (-4,6)	9,6 (9,4)	-0,8 (-0,3)	4,8 (5,2)	-6,4 (-6,0)	0,1 (0,3)
Ib	-1,9 (-2,7)	0,5 (-0,2)	-0,3 (-1,1)	-5,3 (-5,6)	10,0 (9,7)	-4,3 (-4,5)	10,1 (10,4)	-4,0 (-4,3)	-0,1 (-0,3)
IIa	-1,1 (-0,7)	1,2 (1,1)	-0,2 (-0,3)	-5,2 (-5,1)	5,3 (5,5)	-2,6 (-1,7)	8,0 (7,2)	-6,6 (-6,5)	0,3 (0,7)
IIIa	-0,9 (-0,6)	1,2 (1,0)	-0,3 (-0,5)	-1,9 (-1,8)	-6,5 (-6,3)	-0,2 (0,7)	8,2 (7,2)	-6,5 (-6,4)	0,9 (1,0)
IIIb	-1,1 (-0,9)	1,3 (1,2)	-0,8 (-1,0)	-2,6 (-2,8)	-5,7 (-6,0)	-4,3 (-3,5)	13,4 (12,4)	-4,6 (-4,7)	0,3 (0,4)
IVa	-3,7 (-2,9)	0,7 (0)	-0,4 (-1,1)	-25,7 (-26,8)	30,7 (30,6)	-10,2 (-10,3)	7,0 (6,4)	-8,6 (-9,0)	1,2 (0,8)
IVb	-3,9 (-3,2)	0,8 (0,2)	-0,9 (-1,6)	-27,2 (-27,8)	31,3 (30,9)	-14,0 (-14,5)	12,4 (11,6)	-6,5 (-7,3)	0,7 (0,2)
VIa	-1,5 (-1,4)	1,3 (1,1)	9,4 (9,0)	-7,5 (-7,5)	-0,4 (-0,4)	-2,5 (-2,9)	6,2 (5,9)	-4,9 (-5,2)	0,3 (0,1)
VIb	-1,6 (-1,7)	1,7 (1,3)	8,7 (8,5)	-8,5 (-8,5)	-0,2 (-0,1)	-6,9 (-7,1)	11,1 (11,1)	-3,3 (-3,5)	-0,3 (-0,5)
VIIIa	-2,6 (-1,9)	-6,0 (-6,1)	14,1 (12,0)	-8,3 (-8,1)	-0,5 (-0,6)	-2,0 (-2,4)	6,4 (6,0)	-5,9 (-4,5)	-1,8 (-2,0)
VIIIb	-2,3 (-2,2)	-5,7 (-5,9)	13,2 (11,5)	-8,9 (-9,1)	-0,3 (-0,3)	-6,3 (-6,6)	11,4 (11,2)	-4,5 (-2,8)	-3,5 (-2,6)
IXa	7,7 (7,0)	1,1 (1,2)	0,8 (0,7)	-4,0 (-3,8)	-1,0 (-1,1)	-2,8 (-2,6)	4,8 (4,8)	-5,7 (-5,2)	-1,7 (-1,5)
IXb	7,6 (6,7)	1,3 (1,4)	0,2 (0,2)	-4,8 (-4,8)	-0,8 (-0,8)	-6,9 (-6,8)	9,7 (10,0)	-3,5 (-3,4)	-2,3 (-2,1)
Xa	7,5 (9,0)	9,3 (10,4)	-0,2 (-0,7)	-4,8 (-4,3)	-1,1 (-1,2)	-3,8 (-3,6)	4,5 (4,6)	-7,2 (-6,8)	-0,9 (-1,6)
Xb	7,6 (8,7)	9,5 (10,6)	-0,8 (-1,2)	-5,3 (-5,3)	-0,8 (-0,9)	-7,7 (-7,8)	9,5 (9,8)	-4,6 (-5,1)	-1,2 (-2,2)
XIa	6,7 (6,6)	1,8 (1,9)	10,2 (8,9)	-8,5 (-7,8)	-1,2 (-1,4)	-2,3 (-3,0)	6,4 (5,2)	-6,2 (-5,6)	-1,7 (-1,7)
XIIa	6,7 (6,1)	1,0 (1,1)	0,2 (0)	-4,9 (-4,9)	8,6 (8,4)	-0,8 (-0,4)	4,3 (4,5)	-6,9 (-6,4)	-1,7 (-1,5)
XIIb	6,8 (5,8)	1,4 (1,3)	-0,3 (-0,5)	-5,4 (-5,9)	8,9 (8,7)	-4,6 (-4,6)	9,3 (9,7)	-4,6 (-4,7)	-2,1 (-2,1)
XIIIa	5,7 (5,7)	1,8 (1,8)	9,3 (8,2)	9,1 (8,9)	8,7 (8,1)	-0,4 (-0,8)	6,1 (4,9)	-7,6 (-6,9)	-1,6 (-1,7)
XIIIb	6,1 (5,4)	2,0 (2,0)	7,5 (7,7)	-9,5 (-9,9)	8,3 (8,4)	-5,2 (-5,0)	9,9 (10,1)	-4,9 (-5,2)	-2,3 (-2,3)

calculated by means of the additive scheme in Table 3. Proceeding from the satisfactory agreement of these data we calculated the increments of the Br and OCH<sub>3</sub> groups in Va and Vb and VIIa and VIIb (Table 2). On the basis of the additive contribution of the substituents to the <sup>13</sup>C chemical shifts in the spectra of Ia, b, XIIa, b, and XIIIa, b we changed the assignment of the C<sub>5</sub> and C<sub>7</sub> signals in the spectrum of the I molecule made in [5].

When the quinoline molecule is substituted in the benzene ring (in the 6 position), the  $\Delta\delta_\alpha$  values of the substituents do not differ substantially from those in monosubstituted benzenes. The differences in the  $\Delta\delta_o$  values of the substituents in I-III are due to the differences in the change in the charge (q) on the carbon atoms [1]. In IV polarization of the C<sub>5</sub>-H bond as a consequence of steric hindrance is superimposed on this effect. According to the results of the calculation within the CNDO (complete neglect of differential overlap) approximation,  $\Delta q = -0.08$  and  $-0.05$  e, respectively, in IV on the C<sub>5</sub> and C<sub>7</sub> carbon atoms, which, according to the data in [1], amounts to  $\sim -16$  and  $-10$  ppm. The corresponding  $\Delta\delta_o$  values for the OCH<sub>3</sub> group in IV are  $-23.3$  and  $-7.8$  ppm, and it may be assumed that the A conformation is realized primarily in solution in CDCl<sub>3</sub>. This conformation is also retained in the IVa, b molecules (Table 1).



It may be assumed that the overall effect of substituents on the chemical shifts of the carbon atoms in the ortho positions in the examined compounds remains virtually the same as in substituted benzenes. In the spectra of I-IV the shift of the C<sub>2</sub> and C<sub>4</sub> signals to strong field, according to the results of the calculation, is associated with an increase in the electron density on these atoms. This can be linked with separation of the para effect of the substituent on the C<sub>9</sub>, C<sub>4</sub>, and C<sub>2</sub> atoms (the  $\Delta\delta_p$  values for the CH<sub>3</sub> and OCH<sub>3</sub> groups are smaller than those in substituted benzenes).

When the XVII molecule is substituted in the pyridine ring, the  $\Delta\delta_\alpha$  and  $\Delta\delta_o$  values of the substituents decrease as compared with benzene derivatives; in the case of VI-VIII this is associated with weakening of the interaction of the substituent with the ring because of steric hindrance. The latter gives rise to a strong-field shift of the C<sub>5</sub> signal (Table 2). The differences in the  $\Delta\delta_o$  values of the OCH<sub>3</sub> group in the VIIa (VIIb) molecules are due partially to the existence of these compounds in the B conformation. It is interesting to note that, despite the absence of any steric hindrance, the Br atom in Va and Vb has extremely low  $\Delta\delta_\alpha$  and  $\Delta\delta_o$  values as compared with those in the III molecule. It is possible that the weak interaction of the substituent with the quinoline ring in this case is associated with the increased electron density on the C<sub>3</sub> atom (in the XVI molecule the charges on the C<sub>3</sub> and C<sub>6</sub> atoms are  $-0.026$  and  $-0.002$ , respectively, [1]). According to the results of the calculation, for example, the coupling of the NH<sub>2</sub> group in the 6 position with the quinoline ring is stronger than that of the NH<sub>2</sub> group in the 3 position, and this leads to a decrease in the C-NH<sub>2</sub> bond length (0.14 and 0.142 nm, respectively).

#### EXPERIMENTAL

The <sup>13</sup>C NMR spectra of the compounds in CDCl<sub>3</sub> were obtained by the method in [1]. Compounds Ia, b-XIIIa, b were synthesized by the method described in [8].

#### LITERATURE CITED

1. I. V. Zuika, Yu. Yu. Popelis, I. P. Sekatsis, Z. P. Bruvers, and M. A. Tsirule, *Khim. Geterotsikl. Soedin.*, No. 12, 1665 (1979).
2. Yu. Yu. Popelis, I. V. Zuika, Z. P. Bruvers, and I. P. Sekatsis, *Khim. Geterotsikl. Soedin.*, No. 5, 657 (1980).
3. I. V. Zuika, Yu. Yu. Popelis, Z. P. Bruvers, A. P. Sturis, Ya. É. Leeis, and M. É. Krasovska, *Khim. Geterotsikl. Soedin.*, No. 6, 801 (1980).
4. I. V. Zuika, Yu. Yu. Popelis, Z. P. Bruvers, D. É. Zaruma, Ya. É. Leeis, and M. A. Tsirule, *Khim. Geterotsikl. Soedin.*, No. 7, 932 (1981).
5. S. R. Johns and R. I. Willing, *Aust. J. Chem.*, 29, 1617 (1976).
6. P. A. Claret and A. G. Osborne, *Org. Magn. Reson.*, 8, 147 (1976).
7. Z. P. Bruvers and I. V. Zuika, *Khim. Geterotsikl. Soedin.*, No. 3, 387 (1980).
8. Yu. A. Bankovskii, *The Chemistry of Chelate Compounds of Mercaptoquinoline and Its Derivatives* [in Russian], Zinatne, Riga (1978).