3. Z. Ya. Krainer, P. F. Gudz', and L. M. Yagupol'skii, Khim. Geterotsikl. Soedin., No. 2, 236 (1973).
4. Z. Ya. Krainer, L. P. Gudz', E. B. Lifshits, and L. M. Yagupol'skii, Usp. Nauchn. Fotogr., 17, 156 (1976).
5. P. Arvin Shrof, Hatif Jaleel, and F. M. Miller, J. Pharm. Sci., 55, 844 (1966).
6. A. I. Kiprianov and I. K. Ushenko, Zh. Obshch. Khim., 15,207 (1945).
7. V. M. Zubarovskii and G. P. Khodot, Zh. Obshch. Khim., 32, 1574 (1962).
8. A. I. Tolmachev, M. A. Kudinova, and N. A. Dervyanko, Khim. Geterotsikl. Soedin., No. 1, 53 (1974).

SPIN–SPIN COUPLING CONSTANTS OF ^{13}C–^{1}H AND ^{1}H–^{1}H IN 4-SUBSTITUTED PYRIDINES

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The spin–spin coupling constants (SSCC) of ^{13}C–^{1}H and ^{1}H–^{1}H in 4-substituted pyridines, C_5H_4NX [X=CH_3, CN, $COCH_3$, $COOCH_3$, $N(CH_3)_2$, NO_2, OCH_3, Cl, Br], were investigated. To determine the constants, the proton-coupled NMR spectra of ^{13}C and ^{13}C-satellites in the PMR spectra of the compounds, recorded for monomolecular solutions of 4-substituted pyridines in DMSO-D_6, were analyzed. The interrelationship of the SSCC of ^{13}C–^{1}H and ^{1}H–^{1}H in 4-substituted pyridines with the analogous constants in monosubstittued benzenes were obtained. The correlations of the constants with the F- and R-parameters of the substituents are discussed.

According to the theoretical investigations conducted earlier [1, 2], the SSCC of ^{13}C–^{1}H and ^{1}H–^{1}H are an effective source of information on the structure and electronic effects in organic compounds. Of special interest is the use of these parameters for investigations of the effects of substitution on the NMR spectra of aromatic and heteroaromatic compounds [3]. Precise values of the SSCC of ^{13}C–^{1}H and ^{1}H–^{1}H have been obtained for a number of monosubstituted benzenes [3, 4] and 2-substituted and 3-substituted pyridines [5], and the similarity of the influence of substituents on the spin–spin interaction of the nuclei in these compounds was established.

In this work we continued an investigation of the parameters of the proton-coupled NMR spectra of ^{13}C and the high-resolution PMR spectra for 4-substituted pyridines. The conditions of the measurements and the selection of the substituents were analogous to those used in [5].

Table 1 presents the values of the chemical shifts of the protons and the SSCC of ^{1}H–^{1}H. In view of the complexity of the analysis of the PMR spectra obtained for the main ^{12}C-isotopomers of the compounds, we additionally used the signals of the ^{13}C-satellites of the protons. As an example, Fig. 1 presents the experimental and calculated PMR spectra of 4-cyanopyridine. The use of such a procedure for the analysis of the PMR spectra permitted a substantial increase in the accuracy of the measurement of the SSCC of ^{1}H–^{1}H in tetrasubstituted pyridines. A comparison of the constants that we obtained with those known previously [6-8] showed that the most reliable results are cited in [8]; however, in this work not all the SSCC of ^{1}H–^{1}H were determined. In the course of the investigations it was also found that the SSCC $J_{H_2H_6}$ changes sign in the transition from compounds containing substituents that can be arbitrarily characterized [5] as electrically neutral and π-acceptors according to their effects on the system studied (the ring of the heterocycle) to compounds with substituents possessing π-donor properties and halogens.

The SSCC of ^{1}H–^{1}H in 4-substituted pyridines were compared with the analogous constants in monosubstituted benzenes [4, 9, 10]. A great similarity of the effects of substitution on the SSCC of ^{1}H–^{1}H was found in these compounds.

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TABLE 1. Chemical Shifts of ^1H, δ (ppm from TMS) and SSCC J_{HH} (Hz) in 4-Substituted Pyridines

Substituent	δ_2	δ_3	δ_{Me}	J_{23}	J_{25}	J_{26}	J_{35}	СКО*
H	8,604	7,395	—	4,91	0,94	−0,13	1,46	0,029
CH_3 †	8,444	7,213	2,317	4,84	0,84	−0,04	1,87	0,023
CN	8,879	7,895	—	5,06	0,95	−0,22	1,74	0,015
$COCH_3$	8,838	7,836	2,658	5,11	0,90	−0,09	1,86	0,012
$COOCH_3$	8,838	7,850	3,933	5,06	0,92	−0,13	1,79	0,018
$N(CH_3)_2$	8,125	6,576	2,933	5,98	0,56	0,19	2,92	0,026
NO_2	9,008	8,157	—	5,52	0,64	−0,07	2,39	0,024
OCH_3	8,417	6,978	3,838	5,79	0,54	0,19	2,74	0,026
Cl	8,599	7,563	—	5,44	0,59	0,23	2,28	0,021
Br	8,505	7,690	—	5,38	0,60	0,20	2,14	0,022

*Mean-square deviations of the experimental and calculated frequencies of the transitions (Hz) for ^{13}C-satellites in the PMR spectrum of $H_{(3)}(H_{(5)})$ protons.
†SSCC $^5J_{H_{(2)}\text{-Me}} = 0.24$, $^4J_{H_{(3)}\text{-Me}} = -0.73$ (±0.03 Hz).

$$J_{H_{(2)}H_{(3)}}\ (\text{in pyridines}) = -4.34 + 1.207 \cdot J_{H_{(2)}H_{(6)}}\ (\text{in benzene});\ r = 0.958;\ S = 0.11;$$

$$J_{H_{(2)}H_{(5)}} = -0.35 + 2.015 \cdot J_{H_{(2)}H_{(5)}};\ r = 0.965;\ S = 0.05;$$

$$J_{H_{(2)}H_{(6)}} = -1.20 + 0.787 \cdot J_{H_{(3)}H_{(5)}};\ r = 0.975;\ S = 0.04;$$

$$J_{H_{(3)}H_{(5)}} = -0.11 + 1.050 \cdot J_{H_{(2)}H_{(6)}};\ r = 0.982;\ S = 0.09.$$

The parameters of the PMR spectra obtained were used for an analysis of the proton-coupled ^{13}C NMR spectra of 4-substituted pyridines. Figure 2 presents the ^{13}C NMR spectra of the monoresonance of 4-bromopyridine. The spectrum of each ^{13}C-isotopomer of the compounds was calculated separately. The spectrum of the $^{13}C_{(2)}$-isotopomer depends substantially on the value of the differential isotopic shift of the protons (in the ^{13}C-isotopomer in comparison with the ^{12}C-isotopomer of the compound). The calculated values of the differential isotopes shifts of the protons $\nu_{35} = \nu_3 - \nu_5$ (−0.32 to +0.02 Hz) correspond to the values obtained earlier for the isotope shifts in the ^{13}C NMR spectra of monosubstituted benzenes [4].

The values of the chemical shifts of the carbons and the SSCC of ^{13}C-^1H in 4-substituted pyridines are cited in Table 2. The error in the determination of most of the SSCC of ^{13}C-^1H is less than 0.1 Hz. A comparison of the SSCC of ^{13}C-^1H in 4-substituted pyridines with the analogous constants in monosubstituted benzenes [4, 5] showed the presence of a linear interrelationship between these parameters. The results are presented in Table 3. There is no correlation only for the SSCC $^4J_{C_{(3)}H_{(6)}}$, which varies relatively weakly under the influence of substitution (0.26 Hz). The slopes of the functions for most of the constants lie in the range 0.9-1.4, which may be evidence in support of the earlier hypothesis [5] of a moderate influence of the nitrogen atom of the heterocycle on the spin–spin interaction of ^{13}C-^1H in the series of substituents studied for pyridines in comparison with substituted benzenes.

For a detailed study of the effects of substitution on the spin–spin interaction of the nuclei in 4-substituted pyridines, we conducted a correlation analysis of the interaction of the SSCC of ^{13}C-^1H and ^1H-^1H with the inductive and resonance parameters of the substituents (F- and R-constants in the interpretation of [11]). The best relationships were obtained for the direct SSCC $^1J_{CH}$ and the SSCC $J_{H_{(2)}H_{(3)}}$.

$$^1J_{C_{(2)}H_{(2)}} = 177.56 + 11.15F + 4.88R;\quad r = 0.988,\ S = 0.65;$$

$$^1J_{C_{(3)}H_{(3)}} = 162.18 + 17.37F + 3.07R;\quad r = 0.953,\ S = 1.63;$$

$$J_{H_{(2)}H_{(3)}} = 4.85 + 1.11F - 1.10R;\quad r = 0.963,\ S = 0.12.$$

TABLE 2. Chemical Shifts of ^{13}C, δ (ppm from TMS) and SSCC $^{n}J_{CH}$ (Hz) in 4-Substituted Pyridines

Substituent	Carbon 2						Carbon 3						Carbon 4				Other carbons	
	δ_2	$^1J_{22}$	$^2J_{23}$	$^3J_{26}$	$^4J_{25}$	CKO	δ_3	$^1J_{33}$	$^2J_{32}$	$^3J_{35}$	$^4J_{36}$	CKO	δ_4	$^2J_{43}$	$^3J_{42}$	CKO	δMe	δC
H	149,57	177,94	3,19	11,08	−0,87	0,030	123,83	163,79	8,35	6,53	−1,62	0,043	136,03	0,74	6,25	0,047	—	—
CH_3*	149,33	176,92	3,18	11,46	−0,60	0,038	124,61	161,43	8,31	5,82	−1,70	0,011	146,68	0,4	6,3	0,060	20,39	—
CN	150,73	184,19	2,33	11,23	−0,62	0,017	125,59	171,51	9,46	5,15	−1,76	0,009	119,42	−0,3	7,7	0,065	—	116,75
$COCH_3$	150,79	180,87	2,63	11,28	−0,60	0,015	121,26	165,67	8,87	5,41	−1,66	0,011	142,53	†	6,23	0,002	26,80	198,05
$COOCH_3$	150,76	181,67	2,72	11,36	−0,54	0,050	122,50	167,54	8,90	5,19	−1,68	0,019	136,79	−0,81	6,57	0,039	52,72	165,15
$N(CH_3)_2$	149,34	173,80	1,42	12,15	−0,14	0,022	106,63	160,62	9,14	4,55	−1,50	0,029	153,87	−0,7	7,1	0,069	38,48	—
NO_2	152,27	185,96	1,38	12,13	−0,18	0,034	116,32	174,68	9,29	3,78	−1,64	0,023	153,52	−4,0	8,6	0,074	—	—
OCH_3	150,88	177,65	1,40	12,62	−0,11	0,042	109,99	163,65	8,70	4,03	−1,52	0,028	165,11	−2,71	8,34	0,035	55,14	—
Cl	151,09	182,08	2,28	12,35	−0,21	0,043	124,06	170,47	8,86	4,32	−1,58	0,020	142,87	−3,51	9,84	0,025	—	—
Br	150,90	182,16	2,14	12,25	−0,43	0,027	127,01	170,96	8,92	4,66	−1,55	0,008	132,01	−3,40	9,99	0,022	—	—

*SSCC: $^4J_{C(2)-Me} = -0.4$, $^3J_{C(3)-Me} = 4.8$, $^2J_{C(4)-Me} = -6.2$ (±0.1 Hz).
†$^nJ_{CH} < 0.2$ Hz in absolute magnitude.

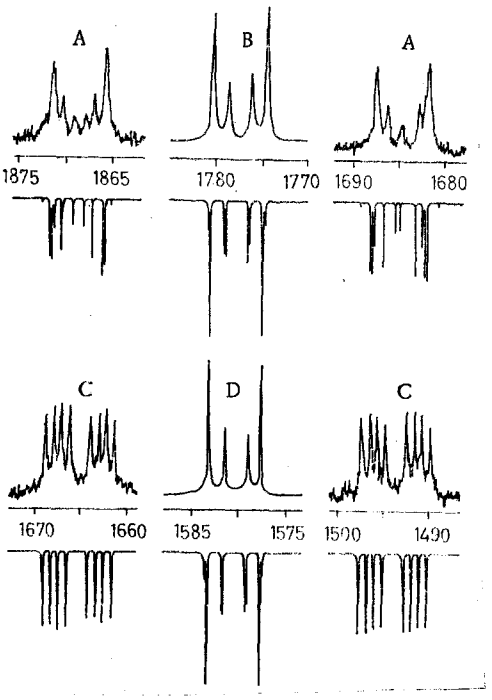

Fig. 1. Experimental and calculated PMR spectra of 4-cyanopyridine. A and C) Spectra of the protons $H_{(2)}$ for the $^{13}C_{(2)}$-isotopomer and $H_{(3)}$ for the $^{13}C_{(3)}$-isotopomer, respectively; B and D) spectra of the main ^{13}C-isotopomer of the compound, protons $H_{(2)}$, $H_{(6)}$, and $H_{(3)}$, $H_{(5)}$, respectively (scale in Hz from TMS).

Satisfactory correlations were also found for the SSCC $J_{H_{(3)}H_{(5)}}$, $^2J_{C_{(2)}H_{(3)}}$, $^2J_{C_{(4)}H_{(5)}}$ and $^3J_{H_{(3)}H_{(5)}}$ ($r > 0.90$); however, on the whole, the investigations conducted confirm the conclusion of [5] that a good quantitative description of the SSCC of ^{13}C-^1H and ^1H-^1H using two-parameter functions analogous to those cited above is impossible.

In conclusion, let us note that the values of the parameters of the PMR and ^{13}C NMR spectra of monosubstituted pyridines obtained in [5] and in this work can be used to establish the structure of nitrogen-containing heterocyclic compounds and to investigate the influence of the electronic properties of the substituents on the PMR spectra.

EXPERIMENTAL

The PMR and ^{13}C NMR spectra were recorded on a Bruker WP-200 SY spectrometer, working in a pulsed system (working frequency of PMR 200.12 MHz, ^{13}C NMR 50.33 MHz), for 1 M solutions of 4-substituted pyridines in DMSO-D_6 containing 3-5% (by volume) TMS. Stabilization was accomplished according to the NMR signal of deuterium of the solvent, temperature 23 ± 2°C.

The conditions of recording of the spectra were analogous to those of [5]. The ^{13}C-satellites of the protons were obtained in the PMR spectra: width of the spectra 500 Hz, digital resolution 0.03 Hz, number of scans more than 50, time of accumulation of the signal 1 h.

The real width of the lines of the spectra (at half the height) in the PMR was 0.2-0.3 Hz for the protons $H_{(3)}$, $H_{(5)}$ and 0.4-0.8 Hz for $H_{(2)}$, $H_{(6)}$ (broadening as a result of interaction with the ^{14}N nucleus of the heterocycle [5]), and in proton-coupled ^{13}C NMR 0.3-0.5 Hz.

All the spectra were calculated with the aid of the PANIC iteration program on an ASPECT-2000 minicomputer. The calculations were performed within the framework of five-spin systems

TABLE 3. Linear Correlations of the SSCC of ^{13}C-^{1}H in 4-Substituted Pyridines ($^{n}J_{CH}^{pyrid}$) with the SSCC of ^{13}C-^{1}H in Monosubstituted Benzenes ($^{n}J_{CH}^{benz}$) [4, 5] of the Type $^{n}J_{CH}^{pyrid} = A \cdot {}^{n}J_{CH}^{benz} + B$ (Hz)

$^{n}J_{CH}$ pyrid	r	S	$^{n}J_{CH}$ benz	A	B	Range of variation of $^{n}J_{CH}$pyrid
$^{1}J_{22}$	0,989	0,55	$^{1}J_{38}$	1,358	−37,67	12,16
$^{2}J_{23}$	0,989	0,10	$^{2}J_{32}$	1,315	1,78	1,79
$^{3}J_{26}$	0,986	0,09	$^{3}J_{35}$	1,365	0,79	1,54
$^{4}J_{25}$	0,976	0,06	$^{4}J_{36}$	1,343	0,92	0,76
$^{1}J_{33}$	0,993	0,54	$^{1}J_{22}$	1,096	−10,13	14,06
$^{2}J_{32}$	0,953	0,11	$^{2}J_{23}$	1,469	6,64	1,15
$^{3}J_{35}$	0,995	0,08	$^{3}J_{26}$	0,898	−0,25	2,75
$^{4}J_{36}$	0,370	—	$^{4}J_{25}$	—	—	0,26
$^{2}J_{43}$	0,995	0,17	$^{2}J_{12}$	0,959	−0,24	4,74
$^{3}J_{42}$	0,995	0,15	$^{3}J_{13}$	1,028	−1,42	3,76

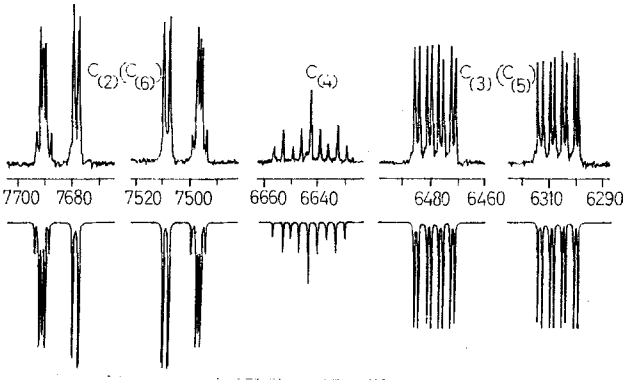

Fig. 2. Experimental and calculated ^{13}C NMR spectra of the monoresonance of 4-bromopyridine (scale in Hz from TMS).

of the ABCDX type, where X is the ^{13}C nucleus (for $^{13}C_{(4)}$-isotopomers — AA'BB'X systems). The SSCC of ^{1}H-^{1}H were calculted from the spectra of ^{13}C-satellites of the protons, enlisting preliminary data of analysis of the proton-coupled ^{13}C NMR spectra. The initial values of the SSCC of ^{13}C-^{1}H and ^{1}H-^{1}H, as well as the differential isotope shifts of the protons, were taken from [4, 5, 8]. The number of lines of the spectra of ^{13}C-satellites of the protons and ^{13}C-NMR assigned in the calculations was 13-17 (for each ^{13}C-isotopomer). The data for pyridine were taken from [5].

The values obtained for the standard errors in the parameters, found in the calculation (considering the digital resolution of the spectra) were up to 0.03 Hz for the SSCC of ^{1}H-^{1}H, with the exception of the SSCC $J_{H_{(2)}H_{(6)}}$ — up to 0.06 Hz; for the SSCC of ^{13}C-^{1}H 0.03-0.05 Hz (with the exception of individual SSCC of $^{13}C_{(4)}$-^{1}H, determined with an accuracy of 0.2 Hz). The chemical shifts of the nuclei were determined according to the complete PMR and ^{13}C-{^{1}H} NMR spectra with an accuracy of $1 \cdot 10^{-3}$ and $2 \cdot 10^{-2}$ ppm, respectively.

Most of the investigated compounds were produced according to the well-known procedures of [12]; the values of the physical constant correspond to those cited in the literature. The finished preparations were subjected to supplementary purification before the recording of the spectra; their purity was analyzed by the methods of thin-layer chromatography and gas–liquid chromatography.

LITERATURE CITED

1. J. B. Stothers, Carbon-13 NMR Spectroscopy, Academic Press, New York (1972), p. 331.
2. J. Emsley, J. Feeney, and L. Sutcliffe, High-Resolution Nuclear Magnetic Resonance Spectroscopy, Pergamon Press (1965).
3. V. A. Chertkov, Dissertation for the Degree of Candidate of Chemical Sciences [in Russian], Moscow (1982).
4. L. Ernst, V. Wray, V. A. Chertkov, and N. M. Sergeyev, J. Magn. Reson., 25, 123 (1977).

5. A. Yu. Denisov, V. I. Mamatyuk, and O. P. Shkurko, Khim. Geterotsikl. Soedin., No. 9 (1984).
6. T. J. Batterham, NMR Spectra of Simple Heterocycles, Wiley, New York (1973), p. 27.
7. Y. Sasaki and M. Suzuki, Chem. Pharm. Bull., 17, 1515 (1969).
8. J. P. Dorie, M. L. Martin, S. Barnier, M. Blain, and S. Odiot, Org. Magn. Reson., 3, 661 (1971).
9. K. Hayamizu and O. Yamamoto, J. Mol. Spectrosc., 25, 422 (1968).
10. K. Hayamizu and O. Yamamoto, J. Mol. Spectrosc., 29, 183 (1969).
11. C. Hansch, A. Leo, S. H. Unger, D. Nikaitani, and E. J. Lien, J. Med. Chem., 16, 1207 (1973).
12. The Chemistry of Heterocyclic Compounds, A. Weissberger, ed., Vol. 14, Interscience, New York—London (1960).

CONVERSIONS OF o-AMINOTRIPHENYLCARBINOL IN THE PRESENCE OF LEWIS ACIDS

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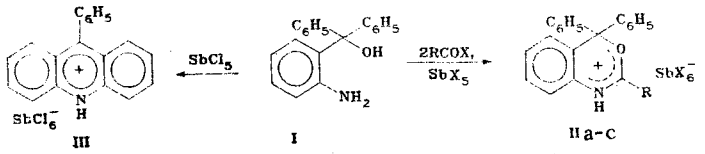
9-Phenylacridinium hexahaloantimonates were produced by the action of antimony pentahalides on o-aminotriphenylcarbinol. The presence of halides of carboxylic acids directs the reaction toward the formation of 4,4-diphenyl-1,2-dihydro-4H-3,1-benzoxazinium hexahaloantimonates.

o-Aminotriphenylcarbinol (I) is converted in acylation to 4H-3,1-benzoxazine [1], while in thermal oxidation it forms 9-phenylacridine [2].

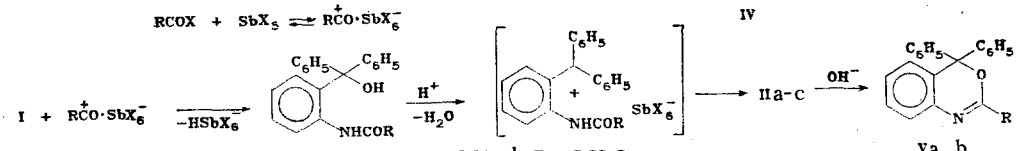
We were the first to investigate the heterocyclization of o-aminotriphenylcarbinol in the presence of Lewis acids. It was established that in the action of acid halides and antimony pentahalides on compound I in the cold in a 1:2:1 ratio, 4H-3,1-benzoxazinium hexachloro-(fluoro)antimonates IIa-c are readily formed. In the absence of acylating agents, 9-phenylacridinium hexahaloantimonates (III) are formed under these conditions.



III I IIa-c

II a $R=C_6H_5$, X=F; b $R=C_6H_5$, X=Cl; c $R=C_4H_3O$, X=Cl

In the presence of an excess of the acid halide, acylation of the amino group and binding of the water liberated during dehydration in acid medium occur first. An equimolar amount of the acid halide is insufficient for the production of the salts IIa-c, since evidently conditions are not created for the acylation of the NH_2 group. For example, at a 2:1 ratio of $SbCl_2$ and PhCOCl, crystals of 9-phenylacridinium III were isolated with a yield of 30%, while the unreacted initial carbinol I was detected in the filtrate by the method of thin-layer chromatography.



IV

V a $R=C_6H_5$; b $R=C_4H_3O$ Va, b

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