# $^{1}H$ AND $^{13}C$ NMR SPECTRA OF BIOLOGICALLY ACTIVE COMPOUNDS.

## V. STEREOCHEMISTRY OF DERIVATIVES OF HEXACHLOROBICYCLO [2.2.1]HEPTENES AND -HEPTADIENES

L. M. Khalilov, A. A. Panasenko, G. G. Balezina,
F. A. Selimov, U. M. Dzhemilev, and G. A. Tolstikov

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The $^{1}H$ and $^{13}C$ NMR spectra of diols of the hexachlorobicycloheptene and -heptadiene series, and also of the diacetates and sulfites corresponding to them, have been investigated. Criteria for the stereochemical assignment of the compounds mentioned on the basis of chemical shifts and spin-spin coupling constants have been determined.

1,2,3,4,7,7-Hexachloro-5,6-di (hydroxymethyl)bicyclo[2.2.1]hepta-2,5-diene (I) and -hept-2-ene (II), which are adducts of the diene condensation of hexachlorocyclopentadiene with but-2-yne- and but-2-ene-1,4-diols, and some of their derivatives having the structure of esters and ether (III-V) and sulfites (VI-IX) (Fig. 1), are known as highly active insecticides and growth regulators [2]. Nevertheless, information on the study of the stereochemistry of such compounds by the spectral methods that are the most informative in this case is extremely limited. Thus, the parameters of the $^{1}H$ NMR spectra of stereoisomeric sulfides — low-melting, α-, (VIII), and high-melting, β-, (IX) — have been given [3. 4] and on this basis, with the use, also, of the methods of dipole moments and IR spectroscopy, structures of the sulfite rings corresponding to each of the isomers have been proposed.

It appeared of interest to find criteria for the assignment of compounds (I-IX) by the $^{13}C$ NMR method. This was all the more the case since there is no information whatever on the stereochemical assignment of some of these compounds (I, III, VI, VII), containing no protons in the bicyclic moiety of the molecule.

The chemical shifts and spin-spin coupling constants $J(^{13}C—^{1}H)$ for the carbon atoms of the compounds under investigation are given in Table 1. The presence of a plane of symmetry in each of the compounds leads to a decrease in the total number of signals in the spectra through their pairwise coincidence. The C-7 carbon atom, lying in the plane of symmetry, is an exception. For diol (I), in the highest-field region a triplet is observed for carbon atoms C-8 and C-9, bearing hydroxy groups. The presence of chlorine atoms at C-1 and C-4 leads to a substantial descreening of these atoms (84.25 ppm) in comparison with the corresponding atoms of the model molecule bicyclo[2.2.1]hepta-2,5-diene (50.9 ppm) [12]. Because of the two α-effects of chlorine atoms, the signal of the bridge carbon atom, C-7 (112.64 ppm) approaches the region of $sp^{2}$-hybridized atoms where are also located the signals of atoms linked by double bonds, C-2 and C-3, and C-5 and C-6, at 136.54 and 143.14 ppm, respectively.

The absence of a double bond in the C-5—C-6 position in diol (II) leads to the appearance in the spectrum of this compound of a strong-field doublet signal of carbon atoms C-5 and C-6 (52.25 ppm). In this case, for the bridge carbon atom C-7 weak screening of about 10 ppm is observed, while on passing from bicyclo[2.2.1]hepta-2,5-diene to bicyclo[2.2.1]·hept-2-ene the effect amounts to 26 ppm [12]. This fact indicates that the effect of the conjugation of the double bonds in a polychlorobicyclo[2.2.1]hepta-2,5-diene is shown feebly, while compound (II) has the endo-configuration of the substituents. The exo-configuration of the two substituents in the bicyclo[2.2.1]heptene moiety would cause an additional screening of the bridge carbon atom of about 8 ppm.

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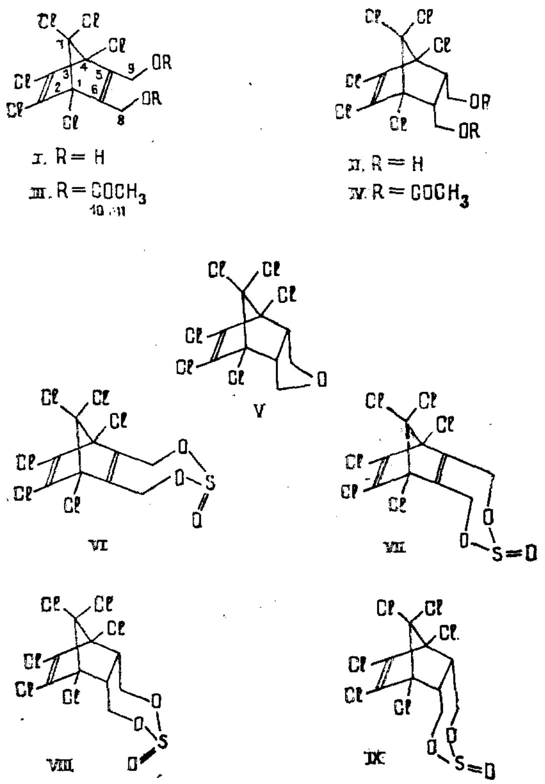

Fig. 1. Structures of Compounds (I)—(IX).

Two additional signals appear in the spectra of the diacetates (III) and (IV) — singlets of the carbonyl carbon atoms at 169.88 and 169.95 ppm and quartets of the methyl radicals of the acetyl groups at 20.75 and 20.73 ppm, respectively. The influence of the acetyl groups extends only to carbon atoms C-2, C-3, C-8, and C-9.

The presence of a furan ring annelated with the C-5—C-6 bond in compound (V) leads to a descreening of the C-8 and C-9 carbon atoms in comparison with the molecule of the diol (II). The small diamagnetic shift of the signals of the carbon atoms of the double bond is due to an increase in the effect of steric compression in the more highly strained molecule (V), which has the endo-configuration of the five-membered ring.

In the dienic derivatives containing a seven-membered ring with a sulfite residue, the differences in the screening of the C-8 and C-9 atoms are due to the different configurations of the sulfite moieties. For the sterically more hindered form (VII) diamagnetic shifts of the signals of the atoms mentioned of about 4 ppm are observed. The analogous effect is expressed more feebly (less than 1 ppm) for the two isomeric sulfites (VIII) and (IX).

Diagnostic signals in the assignment of the isomers (VIII) and (IX) are the signals of the C-5 and C-6 carbon atoms. The interaction of exo-oriented protons at these carbon atoms with the ester oxygen atoms (compound (VIII)) leads to their steric screening by about 1.6 ppm. This conclusion is confirmed by the $^{13}$C NMR spectra taken in the "monoresonance" regime. In the case of the isomer (VIII) a characteristic doublet of doublets is observed for the C-8 and C-9 signals with a difference in the values of the spin-spin coupling constants J($^{13}$C—$^{1}$H) of 8.5 Hz, while for isomer (IX) the corresponding signal appears in the form of an ordinary triplet (J($^{13}$C—$^{1}$H) = 152.3 Hz).

A consideration of Newman projections for the sulfite rings of compounds (VIII) and (IX) (Fig. 2) shows the presence of pseudoaxial protons, H-1 and H-4, at C-8 and C-9 in isomer (VIII), which is what causes the difference in the direct carbon-proton constants of this compound. At the same time, isomer (IX) is characterized by a pseudoequatorial arrangement of the H-1, H-2, H-4, and H-5 protons at these carbon atoms, which, in its turn, leads to the same values of the direct spin-spin coupling constants. The results obtained show that isomer (VIII) belongs to the α- and isomer (IX) to the β- stereochemical series.

TABLE 1. $^{13}C$ NMR Spectra of the Hexachlorobicycloheptenes and -heptadiens Studied (δ, ppm)

| Compound | C-1 | C-2 | C-5 | C-7 | C-8 | Solvent | Method of synthesis |
|---|---|---|---|---|---|---|---|
| I. 1, 2, 3, 4, 7, 7-Hexachloro-5,6-di(hydroxymethyl)bicyclo[2.2.1]hepta-2,5-diene | 84,25 s | 143,14 s | 136,54 s | 112,64 s | 54,13 t | $CD_3OD$ | [5] |
| II. 1, 2, 3, 4, 7, 7-Hexachloro-5,6-di(hydroxymethyl)bicyclo[2.2.1]hept-2-ene | 81,29 s | 131,42 | 52,25 d | 103,33 s | 58,69 t | $CD_3OD : CDCl_3 = 2:1$ | [6] |
| III*. 1, 2, 3, 4, 7, 7 Hexachloro-5,6-di(acetoxymethyl)bicyclo[2.2.1]hepta-2,5-diene | 84,83 s | 143,05 s | 128, 95 | 113,65 s | 56,69 t | $CDCl_3$<br>($^{1}J$ = 150,7) | [5] |
| IV*. 1, 2, 3, 4, 7, 7-Hexachloro-5,6-di(acetoxymethyl)bicyclo[2.2.1]hept-2-ene | 80,71 s | 131,04 s | 47,72 d<br>($^{1}J$ = 139,0) | 102,75 s | 59,69 t<br>($^{1}J$ = 147,5) | $CDCl_3$ | [7] |
| V. 1, 2, 3, 4, 7, 7-Hexachloro-5,6-(epoxydimethyl)bicyclo[2.2.1]hept-2-ene | 80,34 s | 129,51 s | 53,57 d<br>($^{1}J$ = 148,0) | 103,53 | 66,81 t<br>($^{1}J$ = 148,5; d<br>$^{2}J$ = 9,3) | $CDCl_3$ | [8] |
| VI. α-1, 2, 3, 4, 7, 7-Hexachlorobicyclo[2.2.1] hepta-2,5-dien-5,6-di(ylmethyl)sulfite | 83,82 s | 142,82 s | 137,35 s | 113,97s | 59,62 t | $CDCl_3$ | [9] |
| VII. β-1, 2, 3, 4, 7, 7-Hexachlorobicyclo[2.2.1]-hepta-2,5-diene-5,6-di(ylmethyl)sulfite | 85,60 s | 144,47 s | 137,88 s | 113,97s | 55,52 t | $CDCl_3 : CD_3OD = 1:5$ | [9] |
| VIII. α-1, 2, 3, 4, 7, 7-Hexachlorobicyclo[2.2.1] hept-2-ene-5,6-di(ylmethyl)sulfite | 80,45 s | 131,85 s | 51,71 d<br>($^{1}J$ = 132,6<br>d $^{2}J$ = 8,3<br>t $^{3}J$ = 2,0) | 103,79 s | 56,87 dd<br>($^{1}J$ = 153,3<br>$^{1}J$ = 144,8 d<br>$^{2}J$ = 3,4) | $(CD_3)_2CO$ | [10] |
| IX. β-1, 2, 3, 4, 7, 7-Hexachlorobicyclo[2.2.1] hept-2-ene-5,6-di(ylmethyl)sulfite | 81,83 s | 131,96 s | 53,12 d<br>($^{1}J$ = 134,8) | 104,68 s | 56,37 t<br>($^{1}J$ = 152,3) | $CDCl_3$ | [10] |

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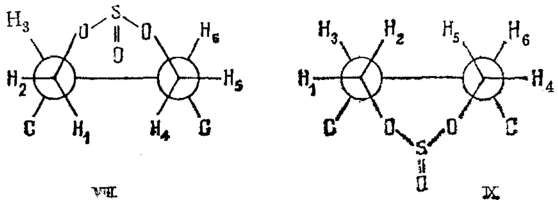
* $\delta C_{10}$—169,98 s, $\delta C_{11}$—20,75 q.

** $\delta C_{10}$—169,95 s, $\delta C_{11}$—20,73 q.



VIII IX

Fig. 2. Newman projections of compounds (VIII) and (IX).

For isomer (VIII), on the basis of the experimental $^1H$ NMR spectrum (100 MHz) we determined test values of the vicinal SSCCs. As a result of iteration analysis with a mean square error of 0.071 we established the following values of the CSs and the SSC constants (Hz).

$\nu_A = \nu_{A'} = 472{,}993 \pm 0{,}006$
$\nu_B = \nu_{B'} = 409{,}153 \pm 0{,}007$
$\nu_X = \nu_{X'} = 359{,}095 \pm 0{,}006$
$J_{AB} = J_{A'B'} = -12{,}912 \pm 0{,}010$
$J_{AX} = J_{A'X'} = 11{,}859 \pm 0{,}011$
$J_{AX'} = J_{A'X} = 0{,}333 \pm 0{,}012$
$J_{AB'} = J_{A'B} = -0{,}048 \pm 0{,}010$
$J_{A'A} = -0{,}030 \pm 0{,}010$
$J_{BX} = J_{B'X'} = 3{,}842 \pm 0{,}011$
$J_{BX'} = J_{B'X} = -0{,}366 \pm 0{,}011$
$J_{BB'} = -0{,}157 \pm 0{,}012$
$J_{XX'} = 8{,}769 \pm 0{,}011$

From the calculated parameters we obtained the theoretical spectrum for a working frequency of 60 MHz, which agreed completely with that published by Forman et al. [3].

Thus, by an analysis of the $^{13}C$ NMR spectra of a number of 5,6-substituted hexachlorobicyclo[2.2.1]heptenes and -heptadienes we have determined criteria for their stereochemical assignment on the basis of the chemical shifts of the C-7 signal, and for the sulfites, in addition, we have established criteria for their assignment to the α- or the β- stereochemical series from the C-5 and C-6 diagnostic signals.

## EXPERIMENTAL

$^{13}C$ NMR spectra were recorded on a JEOL FX 90 Q (22.5 MHz) spectrometer with broad-band incomplete suppression and without suppression for protons with retention of the Overhauser effect. TMS was used as internal standard. Scanning of the field at 4000 and 5000 Hz, the resolution of the analog-digital converter being 0.5 and 0.75 Hz. The pulse delay was 3 sec and its length 6 μsec (33°). The initial hexachlororcycloheptenes and -heptadienes were obtained by published methods [5-10]. The results of the elementary analyses of the compounds agreed with the calculated figures. The thin-layer and column varieties of chromatography were used to separate α- and β-isomers (VI, VII, and VIII, IX). The individuality of all the compounds was confirmed with the aid of GLC analysis [11].

## SUMMARY

Criteria of the stereochemical assignment of 5,6-substituted hexachlorobicyclo[2.2.]] heptenes and -heptadienes have been determined on the basis of chemical shifts and spin-spin coupling constants in the $^{13}C$ NMR spectra.

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# SYNTHESIS OF THE p-TOLUENESULFONATE OF OLEYL ACOHOL UNDER CONDITIONS OF PHASE-TRANSFER CATALYSIS

G. G. Verba, N. Ya. Plugar',
and A. A. Abduvakhabov,

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The tosylation of oleyl alcohol under the conditions of phase-transfer catalysis has been studied. In this process oleyl p-toluenesulfonate of formed with a yield of up to 80%.

The p-toluenesulfonate of oleyl alcohol (octadec-cis-9-en-1-ol) is the main synthon in the synthesis of tricos-cis-9-ene — the pheromone of the house fly Musca domestica L. [1]. The use for these purposes of the p-toluenesulfonate of octadec-cis-14-en-1-ol is also known [2]. The tosylation of the alcohols has been performed with the use as condensing agent of triethylamine or pyridine at a temperature of —10 to 0°C for 15 h [1, 2].

The production of a number of sulfonic esters with the use of benzyltrimethylammonium chloride as phase-transfer catalyst has been described [3].

In order to simplify the method of synthesis and to shorten the reaction time we have studied the conditions for the tosylation of oleyl alcohol with the use of phase-transfer catalysis:

$$CH_3(CH_2)_7CH{=}CH(CH_2)_8OH \rightarrow CH_3(CH_2)_7CH{=}CH(CH_2)_8{-}OTs.$$

The two-phase system benzene —30% aqueous NaOH was used. Tetrabutylammonium iodide (TBAI), tetraethylammonium iodide (TEAI), tetramethylammonium bromide (TMAB), and dibenzo-18-crown-6 (DB18C6) were selected as phase-transfer catalysts. In all cases the reaction was performed at 20-25°C with a molar ratio of oleyl alcohol to p-tolenesulfonyl chloride of 1:1.1. The ratio of oleyl alcohol to catalyst was varied from 1:0.04 to 1:0.4. The course of the reaction was monitored by TLC. It follows from the experimental results, which are given in Table 1, that the tosylation reaction takes place most effectively at a molar ratio of oleyl alcohol to phase-transfer catalyst of 1:0.2, the best of the catalysts proving to be TBAI, with the use of which the reaction was complete in 6 h with an 80% yield of tosylate.

## EXPERIMENTAL

IR spectra were taken on a UR-20 instrument in carbon tetrachloride, and PMR spectra on a Varian XL-200 spectrometer in deuterochloroform with TMS as internal standard.

Thin-layer chromatography was performed on Silufol UV 254 plates (Czechoslovakia) in the ether—hexane (1:1) system. The revealing agent was iodine vapor.

Column chromatography was conducted on silica gel L 100/250 μm at a ratio of substance to sorbent of 1:30, with ether—hexane (1:1) as the eluent.

The p-toluenesulfonyl chloride was purified by Pelletier's method [4].

Oleyl p-Tolunesulfonate. A solution of 2.1 g (0.011 mole) of p-toluenesulfonyl chloride in 5 ml of benzene was added dropwise with vigorous stirring to a heterogeneous mixture of 10 ml of benzene, 2.68 g (0.01 mole) of of oleyl alcohol, 0.74 g (0.002 mole) of tetrabutyl ammonium iodide, and 5 ml of 30% aqueous NaOH solution, the temperature of the reaction mixture being kept at 20-25°C. After predetermined intervals of time, samples were taken from

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