in MeCN, and excess sulfur was separated by filtration. On concentration of the filtrate, crystals separated out, which were recrystallized from MeCN. Yield, 2.4 g (70%), mp 120-121°C, $\delta^{31}P$ 42 ppm (DMFA, C_5H_5N), IR spectrum (ν, cm^{-1}): 2500 br (oil). Found: C 67.47; H 5.66; P 6.91; N 3.47%. $C_{25}H_{25}PO_2PNS$. Calculated: C 67.42; H 5.62; P 6.97%; N 3.15%.

Complex of diphenylboryloxy(hydroxymethyl)phenylphosphine sulfide with Et_3N (III) was obtained in the same way as (II) from 2,2,5-triphenyl-5-hydroxymethyl-2-boronata-5-phosphonia-1,3-dioxane by the action of Et_3N. Yield, 75%, mp 133-146°C, $\delta^{31}P$ 26 ppm (MeCN, C_5H_5N), IR spectrum (ν, cm^{-1}): 2500, 2650 (oil). Found: C 67.10; H 7.34; P 6.47%. $C_{26}H_{35}PBNSO_2$. Calculated: C 66.81; H 7.49; P 6.64%. The product crystallizes well, the wide range of melting is probably due to tautomerism.

Preparation of (II) from (III). A 0.5-g portion of (III) was dissolved in 5 ml of C_5H_5N and the solvent was evaporated in vacuo (0.1 mm) at 40-50°C. The residue was a viscous liquid. IR spectrum (ν, cm^{-1}): 3380. On standing, the liquid completely passed into a solid compound, which was crystallized from MeCN. Yield, 0.33 g (71%), mp 120-121°C, $\delta^{31}P$ 42 ppm (DMFA).

Preparation of (III) from (II). A 0.5-g portion of (II) was dissolved in 5 ml of EtOH and 0.2 g of Et_3N were added. On standing, crystals separated out, which were recrystallized from MeCN. Yield, 0.35 g (64%), mp 133-146°C, $\delta^{31}P$ 26 ppm (MeCN).

CONCLUSIONS

Complexes of diphenylboryloxymethyl(hydroxymethyl)phenylphosphine sulfide exist in both open and cyclic forms.

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SPIN-LABELED ORGANOPHOSPHORUS CHOLINOLYTICS

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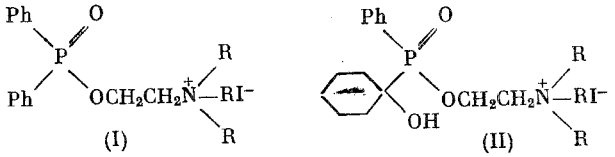
In the investigation of the structure and properties of different biological objects, paramagnetic analogs and models of physiologically active compounds are often used, including phosphorus-containing compounds [1]. Most of the phosphorus-containing nitroxyl radicals are obtained from chlorides and other derivatives of P(III) and P(V) acids, and are esters or amides of phosphorous and phosphoric acids [2].

It is known that esters of diphenylphosphinic acid, containing an ammonium N atom at the β-position of the alkoxyl radical of (I), have anticholine esterase and nitotinolytic activity [3, 4]. Similar compounds, i.e., esters of phenyl-α-hydroxycyclohexylphosphinic acid (II) are muscarinic cholinolytics and reciprocal inhibitors of choline esterases [5]



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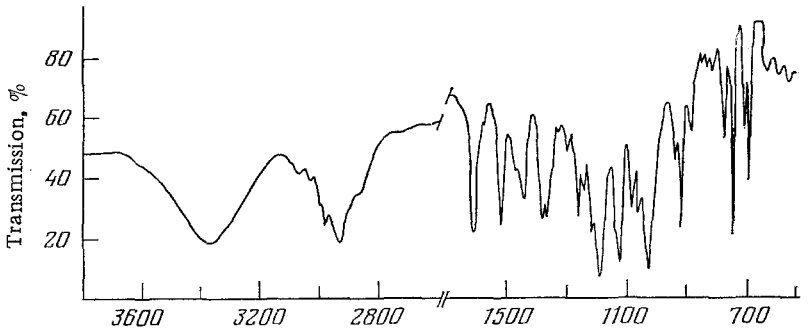
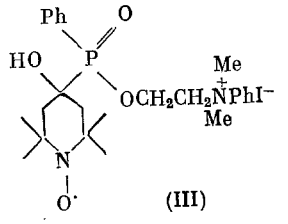


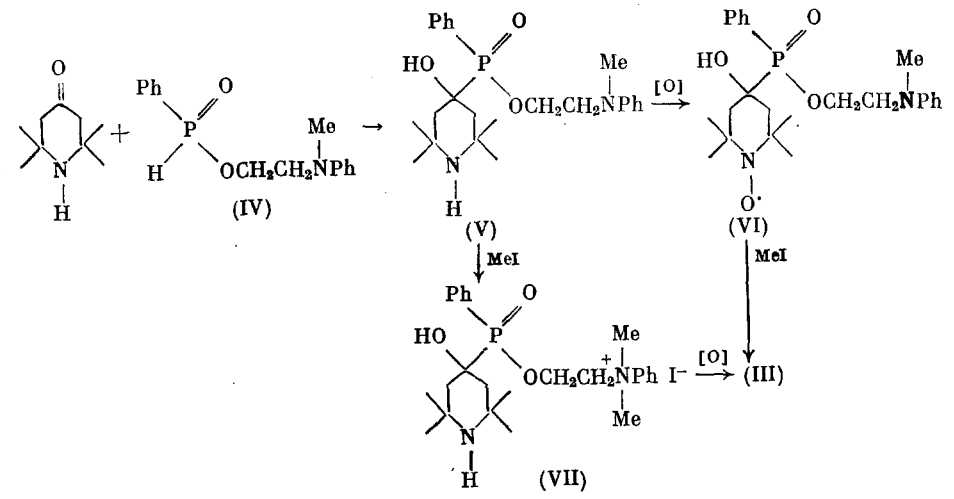
Fig. 1. IR spectrum of 4-hydroxy-4-[β-(N-methyl-N-phenyl)amino-ethyl]-phenylphosphinyl-2,2,6,6-tetramethylpiperidine-1-oxyl (VI) in KBr.

For the study by the EPR method, we synthesized an organophosphorous nitroxyl radical (III) containing structural fragments leading to the appearance of the cholinolytic and anti-choline esterase activity



(III)

The nitroxyl radical (III) was synthesized by the Abramov reaction from triacetoneamine and hydrophosphoryl compound (IV) by schemes already proposed in [6, 7]



The addition of the hydrophosphoryl compound (IV) to the carbonyl group of triacetone-amine proceeds under mild conditions (ether, ~20°C). The addition product (V) was oxidized by $PhCO_3H$ into radical (VI). If other oxidizing agents are used, i.e., H_2O_2 in the presence of Na_2WO_4 or m-chloroperbenzoic acid, radical (VI) cannot be obtained. Compound (VI) was iodomethylated with the formation of iodomethylate (III) in an excess of the reagent [5, 6].

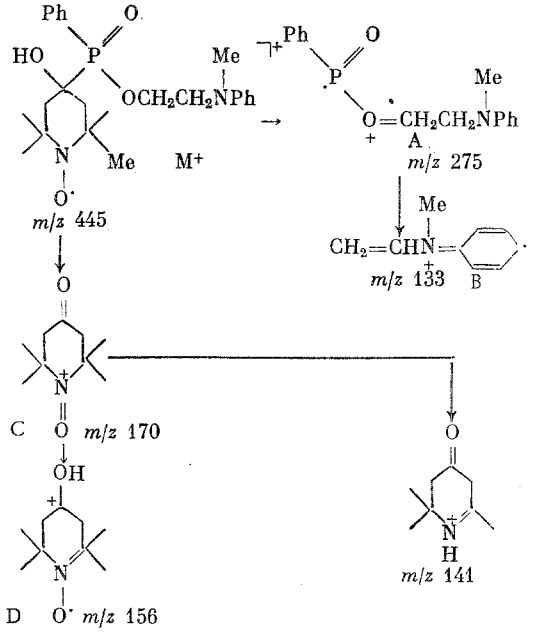
The structure of amines (V) and (VII) and radicals (III) and (VI) was confirmed by a series of data of elemental analysis, IR, UV, mass and NMR spectra, and that of radicals (III) and (VI) by EPR spectra. In the IR spectra of these compounds there are bands of the stretching vibrations of the OH group in the 3270-3370-cm^{-1} region, of the phenyl ring in the 1600-

cm^{-1} region, of the phosphoryl group (P=O) at the 1200-cm^{-1} region, and of the PO group in the 1000-cm^{-1} region (Fig.1).

In the UV spectrum of radical (VI) the phenyl chromophore band with a vibrational structure is masked (shoulder at 272 nm (ε 3064)) by the absorption of the dialkylaniline chromophore at λ_{max} 256 (ε 18,300) due to electron transfer. The band with λ_{max} 298 nm (ε 2500) is due to local excitation of the phenyl ring. The spectrum of the radical in the visible region contains a band at 445 nm (ε 10) due to the **n→π*-transition** of the nitroxyl group. The ^{31}P NMR spectrum of radical (VI) contains one peak with δP 42.3 ppm, and that of amine (V) — a peak with δP 42.48 ppm. The mass spectra of compounds (III), (V), (VI) contain low-intensity peaks of the molecular ions of (V) and (VI), and fragments of the dissociation of the molecules at the C—P bond. The scheme of the dissociation of the molecular ion of radical (VI) is illustrated below. In the spectrum of the radical there is no peak of $M^+ - 30$, which indicates low stability under the electron impact of the bond between the P atom and the heterocyclic ring. This is also indicated by the presence in the spectrum of an intense peak of $[M - R^{\bullet}]^+$ with m/z 275 and fragments of the dissociation of the 4-hydroxy-2,2,6,6-tetramethylpiperidine-1-oxyl ring with m/z 156 and 141. In the mass spectrum of radical (VI) there is a high-intensity peak of $R^{\bullet} - 15$, which is usually characteristic of amines [8]. The ion with m/z 275 dissociates with splitting of the phosphonate fragment and an ion with m/z 133. The structure of the above ions was confirmed by a high resolution spectrum (given are ion, m/z, and empirical formula): A, 275,1100, $C_{15}H_{18}NO_2P$; C, 170,1172, $C_9H_{16}NO_2$; D, 156,1018, $C_8H_{14}NO_2$; B, 133,0893, $C_9H_{11}N$.

The EPR spectra of radicals (III) and (VI) have the form of a triplet signal with a hyperfine interaction constant a_N = 17 Oe, characteristic of all nitroxyls. The paramagnetism corresponds to a content of $6.0 \cdot 10^{23}$ spins/mole.

To verify the alternative paths of synthesis of (III), we studied the action of MeI on amine (V), which, in principle, could proceed with respect to both the sterically hindered amino group of piperidine and the tertiary aromatic amino group. A product is formed in the reaction, which according to elemental analysis and spectral data corresponds to structure (VII) (see Experimental). It can be shown that iodomethylation took place at the aromatic N atom by the fact that in the analytical experiment (directly in the EPR ampule), in the oxidation of amine (VII) by both $PhCO_3H$ and by H_2O_2 in the presence of Na_2WO_4, a nitroxyl radical is formed with a triplet EPR spectrum (a_N = 17.1 Oe in water). Radical (III) can be used as a spin probe in the study of choline esterases and muscarinic choline receptors.



EXPERIMENTAL

The IR spectra were recorded on the UR-10 spectrometer, UV spectra on a Specord UV VIS spectrophotometer, the ^{31}P NMR spectra were obtained on a Bruker HZ-90 apparatus with a working frequency of 36.43 MHz with reference to 85% H_3PO_4, and the EPR spectra on a Varian E-4 radiospectrometer.

[β-(N-Methyl-N-phenyl)aminoethyl]phenylphosphonite (IV) was obtained by the method described in [6].

4-Hydroxy-4-[β-(N-methyl-N-phenyl)aminoethyl]phenylphosphinyl-2,2,6,6-tetramethylpiperidine (V). A solution of triacetoneamine in absolute ether was added to a solution of 1.3 g of (IV) in absolute ether, and the mixture was left to stand for two days. The white crystals that precipitated were filtered, dissolved in chloroform, and the chloroform solution was washed with a 5% potassium carbonate; the organic layer was separated, and washed with water. Chloroform was evaporated, and the residue was washed with hot hexane and recrystallized from MeCN. Yield, 1.75 g (81%) of a product, mp 141-143°C. IR spectrum (KBr, ν, cm^{-1}): 1210 (P=O), 1600 (C=C, phenyl), 3300 (O-H). ^{31}P NMR spectrum: δP 42.48 ppm. Found: C 67.4; H 8.3; P 7.0%. $C_{24}H_{35}N_2O_3P$. Calculated: C 67.0; H 8.7; P 7.2%.

4-Hydroxy-4-[β-(N-methyl-N-phenyl)aminoethyl]phenylphosphinyl-2,2,6,6-tetramethylpiperidine-1-oxyl (VI). A 0.8-g portion of 78% $PhCO_3H$ was added gradually to a solution of 1.4 g of (V) in THF, and the mixture was left to stand for 2 h. Tetrahydrofuran was evaporated, benzene was added, and the mixture was washed twice with potassium carbonate solution and water. The benzene solution was dried over Na_2SO_4, benzene was evaporated, and the residue was recrystallized from MeCN. Yield, 87%, mp 158-160°C (red crystals). IR spectrum (KBr, ν, cm^{-1}) 1200 (P=O), 1500 (C=C, phenyl), 3370 (OH). ^{31}P NMR spectrum: δP 42.3 ppm. EPR spectrum $6.0 \cdot 10^{23}$ spins/mole. Found: C 65.3; H 7.8; P 6.6%. $C_{24}H_{34}N_2O_4P$. Calculated: C 64.8; H 7.7; P 6.9%.

4-Hydroxy-4-[β-(N-methyl-N-phenyl)aminoethyl]phenylphosphinyl-2,2,6,6-tetramethylpiperidine-1-oxyl Iodomethylate (III). A 1.0-g portion of (VI) was dissolved in acetone, and a fivefold excess of MeI was added. The mixture was left to stand for 24 h. The orange crystals were filtered, and washed with cold acetone. Yield quantitative, mp 117-120°C. IR spectrum (KBr, ν, cm^{-1}) 1200 (P=O), 3370 (OH). Found: C 50.5; H 6.6; I 21.5%. $C_{25}H_{37}N_2O_4PI$. Calculated: C 51.0; H 6.4; I 21.6%.

4-Hydroxy-4-[β-(N-methyl-N-phenyl)aminoethyl]phenylphosphinyl-2,2,6,6-tetramethylpiperidine (VII). A fivefold excess of MeI was added to a solution of 1.0 g of (V) in acetone. The mixture was left to stand for 24 h, the crystals were filtered, and washed with cold acetone. Yield quantitative, mp 205-206°C. IR spectrum (KBr, ν, cm^{-1}): 1200 (P=O), 1600 (C=C, phenyl), 3270 (OH), 1050 (POC). Found: C 52.0; H 6.9; I 22.4%. $C_{25}H_{38}N_2O_4PI$. Calculated: C 52.5; H 6.7; I 22.2%.

The authors wish to express their gratitude to B. V. Rozynov for recording the high-resolution mass spectrum of radical (VI).

CONCLUSIONS

An organophosphorus nitroxyl radical was synthesized for use as spin-probe.

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MECHANISM OF HOMOLYSIS OF M—C BONDS IN GROUP IVB ORGANOMETALLIC DERIVATIVES OF o-SEMIQUINONES

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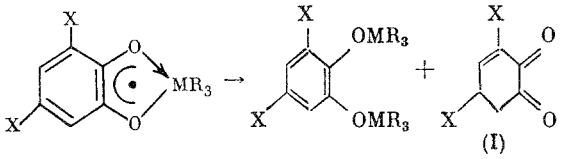
Organometallic derivatives of o-semiquinones with group IVB metals ($SQMR_3$) where SQ is 3,5-di-tert-butyl-1,2-benzosemiquinone undergo interconversions in two directions [1-3]:

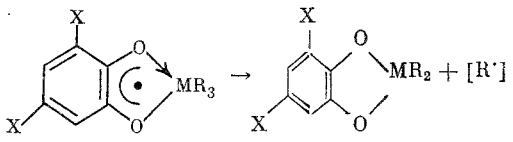
1. Disproportionation to the quinone (Q) and the corresponding catecholate ($Cat(MR_3)_2$, MR_3=$SiMe_3$, $GeEt_3$)



(I)

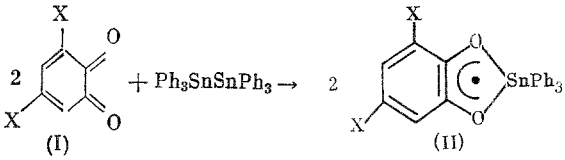
Here and later X = t-Bu.

2. Homolytic rupture of the M—C bond in which the process is formally described by the equation



The mechanism of rupture of the M—C bonds in the process of breakdown of organometallic derivatives of o-semiquinones is discussed in the literature [2-5], in which both mono and bimolecular character were suggested for the transformations. However, up to the present time no clear-cut preference for any one of the indicated pathways is in evidence (for example, see [4]). In our previous works devoted to investigation of group IVB derivatives of o-semiquinones [1-3, 6] a preference was expressed for the bimolecular character of these processes.

We carried out a kinetic investigation of the breakdown of 3,5-di-tert-butyl-o-benzosemiquinolate of triphenyltin (II). The choice of (II) for investigation was due to its relative stability in the series of group IVB organometallic derivatives of o-semiquinones and a convenient method of synthesis of the radical by the reaction



(I) (II)

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