CONCLUSIONS

1. 4-tert-Butoxy-2,6-di-tert-butylphenoxyl radicals in benzene solution cleave the tert-butyl radical to give 2,6-di-tert-butyl-1,4-benzoquinone.

2. A kinetic analysis of the autooxidation scheme, inhibited by a sterically hindered phenol, shows that decomposition of the phenoxyl leads to an impairment of all of the indices of the antioxidative activity of a phenolic antioxidant.

LITERATURE CITED

- 1. N. M. Emanuél', E. T. Denisov, and Z. K. Maizus, Chain Oxidation Reactions of Hydrocarbons in the Liquid Phase [in Russian], Nauka, Moscow (1965).
- 2. E. T. Denisov, Usp. Khim., <u>42</u>, 361 (1973).
- 3. V. A. Roginskii, Vysokomol. Soedin., 24, 1000 (1982).
- 4. V. A. Belyakov, E. L. Shanina, V. A. Roginskii, and V. B. Miller, Izv. Akad. Nauk SSSR, Ser. Khim., 1975, 2685.
- 5. V. I. Rubtsov, V. A. Roginskii, V. B. Miller, and G. E. Zaikov, Kinet. Katal., 21, 612 (1980).
- E. A. Giezen, Degradation and stabilization of polymers. AKZO Research Laboratories and Institute of Chemical Physics Academy of Sciences USSR. Proceedings of the First Conference, Moscow (1975), p. 91.
- 7. V. D. Pokhodenko, Phenoxyl Radicals [in Russian], Naukova Dumka, Kiev (1969).
- 8. V. A. Roginskii and V. A. Belyakov, Dokl. Akad. Nauk SSSR, 237, 1404 (1977).
- 9. V. A. Roginskii, Kinet. Katal., 23, 500 (1982).
- 10. E. T. Denisov, Usp. Khim., 47, 1090 (1978).
- 11. V. S. Pudov and A. L. Buchachenko, Usp. Khim., 39, 130 (1970).
- 12. M. B. Neiman, in monograph: Chemical Kinetics and Chain Reactions [in Russian], Nauka, Moscow (1966), p. 409.
- 13. C. R. H. I. De Jonge, H. J. Hageman, W. G. B. Haijsmans, and W. J. Mijs, J. Chem. Soc., Perkin Trans. 2, 1973, 1276.

RADICAL NUCLEOPHILIC SUBSTITUTION OF

INACTIVATED HETEROARYL BROMIDES

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Included among the most interesting and promising new types of reactions, which attract the broad attention of investigators, are those that are designated as $S_{RN}1$ radical nucleophilic substitution reactions [1], otherwise also known as reductive nucleophilic substitution processes [2]. The data on them has been recently generalized in several comprehensive reviews [3-5]. The most important variety of such reactions are the transformations of inactivated aryl and heteroaryl halides to difficultly available functional compounds. The chain mechanism [1] proposed for $S_{RN}1$ reactions predicates in the initiation step the one-electron reduction of the haloaromatic compound, which is accomplished via either solvated electrons or photochemically. The formed anion-radical then decomposes to halogen anion and aryl (or hetaryl) radical; the latter on reaction with the nucleophile gives a new anion-radical, the transfer of an electron from which to the starting halide leads to the substitution product and the anion-radical of the haloaromatic compound, thus prolonging the chain.

 $\operatorname{ArX} \xrightarrow{e^{-}} [\operatorname{ArX}]^{-} \xrightarrow{-X^{-}} \operatorname{Ar}^{\cdot} \xrightarrow{\operatorname{Nu}^{-}} [\operatorname{ArNu}]^{-} \xrightarrow{\operatorname{ArX}} \operatorname{ArNu} + [\operatorname{ArX}]^{-}$

Previously we described the one-step synthesis of 3-thienylacetonitrile by the photostimulated reaction of 3-bromothiophene with cyanomethyl anion, which was generated from acetonitrile by treatment with alkyl

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metal amides in liquid ammonia [6]. Our attempts to run the analogous reaction with anions stabilized by two electron-acceptor substituents, which were obtained from malonodinitrile, cyanoacetic ester, and malonic ester, proved unsuccessful. The reason for this remains unanswered as yet, but, judging by certain data (see, for example, [7]), this is a quite common phenomenon for conditions where reactions of the S_{RN1} type usually go. Unsatisfactory results were also obtained when 3-bromofuran is reacted with cyanomethyl anion: the yield of 3-furylacetonitrile was a total of ~10% (compared to ~40% for the thiophene analog).

The use of halopyridines in reactions of the S_{RN1} type seemed much more promising, for which such reactions with acetone enolate are described [8], and also the reaction of 2-chloropyridine with cyanomethyl anion [9]. In this connection we will mention that the usual rules of nucleophilic aromatic substitution are not applicable to S_{RN1} reactions: in its reactivity the inactivated 3-bromopyridine in the reactions with acetone enolates occupies an intermediate position between the 2- and 4-isomers [8].

We studied the reaction of 3-bromopyridine with the cyanomethyl anion. This reaction under photostimulation leads to 3-pyridylacetonitrile in over 80% yield ($\sim 30\%$ in the absence of irradiation and when stimulated by solvated electrons).



Desiring to expand the gamut of the nucleophiles we studied the reaction of 3-bromopyridine with some alkali metal amides and N-alkylamides. However, despite the UV irradiation, the desired products were not obtained: a mixture of the corresponding 3- and 4-aminopyridines was obtained in all cases, which was caused by the action of the alkali metal amide even at -70 °C to give 3,4-dehydropyridine (cf. [10]), which then non-selectively adds amide anion.

$$\bigcup_{N} \stackrel{\text{Br}}{\longrightarrow} + \overline{\text{N}}\text{RR'} \rightarrow \bigcup_{N} \stackrel{\overline{\text{N}}\text{RR'}}{\longrightarrow} \bigcup_{N} \stackrel{\text{NRR'}}{\longrightarrow} + \bigcup_{N} \stackrel{\text{NRR'}}{\longrightarrow}$$

These results caused us to return to a study of the reaction of 3-bromopyridine with cyanomethyl anion in order to be sure that the action of the latter, in contrast to the reaction with a stronger base like amide anion, does not give the dehydropyridine and 3-pyridylacetonitrile is obtained without the 4-isomer as impurity. The authentic sample of 4-pyridylacetonitrile, needed for comparison, was obtained by reacting 4-bromopyridine with with cyanomethyl anion and was analyzed by GLC on a capillary column (see the EXPERIMENTAL SECTION), since the complete separation of the 3- and 4-isomers could not be achieved on packed columns. Actually, 3,4-dehydropyridine is not formed when 3-bromopyridine is reacted with cyanomethyl anion, the same as when another comparatively weak base, namely phenylmercaptide anion, is used as the nucleophile, where the reaction product is phenyl 3-pyridyl sulfide without the 4-isomer as impurity. It should be emphasized that 3-bromopyridine, containing the least labile halogen atom in the group of monobrominated pyridine derivatives, can be made to react with the cyanomethyl and mercaptide ions under the discussed conditions.

EXPERIMENTAL

The chromatographic analyses were run on an LKhM-8MD chromatograph equipped with a flame-ionization detector. Nitrogen was the carrier gas and the following stainless steel columns were used: A) 1300×2 mm, packed with 10% Carbowax 40M deposited on Chromosorb P (120-140 mesh) containing 1% KOH, and B) 1000×2 mm, packed with 5% Apiezon L deposited on Celite 545 (80-100 mesh) containing 1% Na₃PO₄. The 40 m \times 0.25 mm pyrex glass capillary column, packed with Carbowax 40M/KF, was prepared as described in [11]. The quantitative determinations were run using diphenylmethane and nonadecane as the internal standards.

The reactions, stimulated by UV light, were run in the quartz reactor of an apparatus set up for photochemical studies, which was equipped with three lamps of the DRT-220 type and a magnetic stirrer [6]. A molybdenum glass flask was used for the reactions initiated by solvated electrons. All of the reactions were run in a dry argon stream. The KNH_2 was prepared as described in [6].

Reaction of 3-Bromopyridine with Cyanomethyl Anion Using UV Light. To a suspension of KNH_2 , obtained from 2.15 g (55 mmoles) of K in 100 ml of NH_3 , was added at -70° a solution of 2.56 g (62 mmoles) of acetonitrile in 5 ml of abs. ether and then, with stirring and UV irradiation, was added to 5 min a solution of 1.98 g (12.5 mmoles) of 3-bromopyridine (obtained as described in [12]) in 8 ml of abs. ether. The stirred mixture was irradiated for another 30 min at -70° , and then, without irradiation and cooling, was added 5 g of NH_4Cl solution. The ether layer was separated and the aqueous layer was extracted in succession with ether $(2 \times 100 \text{ ml})$ and chloroform $(3 \times 30 \text{ ml})$. The extracts were combined, dried, and a sample was taken for GLC analysis (4% of the extract), to which a known amount of diphenylmethane was added. Based on the GLC analysis (column A), the yield of 3-pyridylacetonitrile was 87%, in which connection it was free of 4-pyridylacetonitrile (capillary column). After distilling off the solvent from the main extract, 3-pyridylacetonitrile was isolated from the residue (1.5 g) by chromatographing on Silica Gel L (40 g, 40-100 μ , eluant = benzene and then a 2:1 benzene – acetone mixture), bp 142-144° (18 mm), n_D^{20} 1.5252; HCl salt, mp 166-168° (in a sealed capillary) (from alcohol); picrate, mp 162-164° (from alcohol); cf. [13, 14]. The hydrolysis of 3-pyridylacetonitrile with alcoholic KOH solution gave 3-pyridylacetic acid, mp 144-146° (from ethyl acetate); cf. [15].

Reaction of 3-Bromopyridine with Cyanomethyl Anion, Initiated by Potassium in Liquid NH₃. To a suspension of KNH₂, obtained from 1.63 g (42 mmoles) of K in 100 ml of NH₃, were added at -70° in succession 2.15 g (52 mmoles) of acetonitrile in 3 ml of abs. ether and 1.58 g (10 mmoles) of 3-bromopyridine in 5 ml of abs. ether, and then, at a temperature ranging from -65 to -68° , was added 0.63 g (16 mmoles) of potassium in pieces until a permanent blue color appeared. Then the reaction mass was treated with excess NH₄Cl (10 g) and worked up as described above. Based on the GLC data (column A), the yield of 3-pyridylacetonitrile was 0.35 g (30%).

Reaction of 3-Bromopyridine with Amide Anion under UV Irradiation. To a suspension of KNH_2 , obtained from 1.8 g (46 mmoles) of K in 100 ml of NH_3 , with stirring and exposure to UV light (-70°), was added in 15 min a solution of 1.58 g (10 mmoles) of 3-bromopyridine in 15 ml of abs. ether. The mixture was irradiated for 30 min and then decomposed and worked up as described above. Based on the GLC data (column A), the reaction products contained traces of the starting 3-bromopyridine, a mixture of the 3- and 4-aminopyridines (~1:1), and also a number of substances with longer retention times. Analogous results were also obtained with the pentamethylene amide anion.

<u>Reaction of 4-Bromopyridine with Cyanomethyl Anion under UV Irradiation.</u> To a suspension of KNH_2 , obtained from 2.4 g (61.5 mmoles) of K in 100 ml of NH_3 , were added at -70° a solution of 2.86 g (70 mmoles) of acetonitrile in 5 ml of abs. ether and 1.18 g (6.05 mmoles) of 4-bromopyridine \cdot HCl (obtained from 4-aminopyridine as described in [16]), and the mixture was irradiated for 40 min at -70° . After working up the reaction mass as described above the extract, based on the GLC data using a capillary column, contained 0.42 g of 4-pyridylacetonitrile (~60%) and was free of 3-pyridylacetonitrile.

Reaction of 3-Bromopyridine with Phenylmercaptide Anion under UV Irradiation. To 2.55 g (23.2 mmoles) of thiophenol and 1.52 g (9.6 mmoles) of 3-bromopyridine in 20 ml of abs. ether was added 110 ml of NH_3 and the stirred mixture was irradiated at -65° for 45 min. To the residue from distilling off the NH_3 was added 50 ml of water and the whole was extracted with ether (3 × 80 ml). The ether extracts were washed with water (25 ml), dried, and the ether was distilled off. Based on the GLC data (column B), the residue contained 0.68 g of 3-bromopyridine (45% recovery) and 0.42 g of phenyl 3-pyridyl sulfide (23% yield when based on taken and 42% when based on consumed 3-bromopyridine). The samples of phenyl 3-pyridyl and phenyl 4-pyridyl sulfides, needed for analysis by the GLC method, were isolated from their mixture, obtained as described in [17] by reacting PhSK and t-C₄H₉OK with 3-bromopyridine in DMSO, by TLC on silica gel, using a 1:1 benzene-acetone mixture for elution.

CONCLUSIONS

The photostimulated radical nucleophilic substitution reactions of 3-bromopyridine with the cyanomethyl and phenylmercaptide anions lead to 3-pyridylacetonitrile and phenyl 3-pyridyl sulfide, respectively.

LITERATURE CITED

- 1. J. K. Kim and J. F. Bunnett, J. Am. Chem. Soc., <u>92</u>, 7463 (1970).
- 2. R. W. Alder, Chem. Commun., 24, 1184 (1980).
- 3. J. F. Bunnett, Acc. Chem. Res., 11, 413 (1978).
- 4. J. F. Wolfe and D. R. Carver, Org. Prep. Proceed. Int., 10, 225 (1978).
- 5. I. P. Beletskaya and V. N. Drozd, Usp. Khim., 48, 793 (1979).
- 6. Ya. L. Gol'dfarb, A. P. Yakubov, and L. I. Belen'kii, Khim. Geterotsikl. Soedin., 1979, 1044.
- 7. M. F. Semmelhack and T. Barger, J. Am. Chem. Soc., 102, 7765 (1980).
- 8. A. P. Komin and J. F. Wolfe, J. Org. Chem., <u>42</u>, 2481 (1977).
- 9. R. A. Rossi, R. H. Rossi, and A. F. Lopez, J. Org. Chem., <u>41</u>, 3372 (1976).

- 10. G. W. Gribe and M. G. Saulnier, Tetrahedron Lett., 21, 4137 (1980).
- 11. R. V. Golovnya, A. L. Samusenko, and E. A. Mistryukov, J. High Resolution Chromatogr. Chromatogr. Commun., 2, 609 (1979).
- 12. R. E. Lokhov, S. S. Lokhova, N. M. Gaidarova, and L. I. Belen'kii, Khim. Geterotsikl. Soedin., <u>1981</u>, 1236.
- 13. S. Okuda and M. M. Robinson, J. Am. Chem. Soc., 81, 740 (1959).
- 14. M. Protiva, J. O. Jilek, and J. Pliml, Coll. Czech. Chem. Commun., <u>16</u>, 344 (1951).
- 15. S. Carboni, Gazz. Chim. Ital., 85, 1194 (1955).
- 16. A. Murray and W. H. Langham, J. Am. Chem. Soc., 74, 6289 (1952).
- 17. W. J. Zoest and H. J. Hertog, Rec. Trav. Chim., <u>93</u>, 166 (1974).

ADDITION OF CHLOROBROMOMALONIC ESTER

TO METHYL ACRYLATE

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Chlorobromomalonic ester (CBM) [1] permits comparing the reactivity of geminal chlorine and bromine atoms under radical addition conditions. Its closest analogs, the dichloro-(DCM) and dibromomalonic (DBM) esters, when initiated by the coordination initiating system (CI) $Fe(CO)_5 + DMF$, react with methyl acrylate (MA) to give the adducts $(C_2H_5OOC)_2CXCH_2CHXCOOCH_3$, X = Cl(I), Br(II) [2, 3]. Here DBM is a more active addendum than DCM. It seemed expedient to study CBM in the reaction with MA using the same initiation method.

It proved that CBM, when initiated using this system, reacts with MA with cleavage of the C-Br bond and gives adduct (III). Together with this, both of the halogen atoms are cleaved from CBM to give 1,1-dicarbethoxy-2-carbomethoxycyclopropane (IV) and tetraethyl ethylene tetracarboxylate (V). The CBM is also reduced slightly to monochloromalonic ester (MCM).

 $(C_{2}H_{5}OOC)_{2}CCIBr + CH_{2} = CHCOOCH_{3} \xrightarrow{Fe(CO)_{s} + DMF} (C_{2}H_{5}OOC)_{2}CCICH_{2}CHBr + (C_{2}H_{5}OOC)_$

The formation of (IV) and (V) indicates the possible carbenoid cleavage of the halogen atoms from $(C_2H_5OOC)_2-CX_2(X = Cl, Br)$ by the Fe(CO)₅.



The intermediate formation of carbenoid particles in the reactions of gem-dihalides with $Fe(CO)_5$ was postulated in [4]. It is known [5] that $C_6H_5COCHBr_2$ reacts with $Fe(CO)_5$ to give trans-1,2,3-tribenzoylcyclopropane. The generation of the carbene $(C_2H_5OOC)_2C$: from diazomalonic ester gives (V) [6, 7]. However, by analogy with [8], another possibility exists for the formation of (IV).



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