REACTION OF 2,4,6-TRIMETHYL- AND 2,4,6-TRIPHENYLPYRYLIUM PERCHLORATES WITH HETEROCYCLIC AMINES

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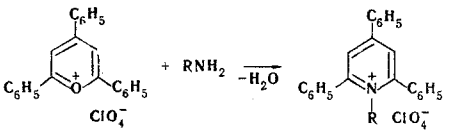
2,4,6-Triphenylpyrylium perchlorate reacts with most heterocyclic amines in dimethylformamide to give quaternary pyridinium salts. 2,4,6-Trimethylpyrylium perchlorate forms similar products only up to a certain limit of the basicity of the amine, below which a proton is transferred from the γ-methyl group of the pyrylium salt to the pyridine nitrogen atom of the heteroring to give the perchlorate of the starting heterocycle. The residual 2,6-dimethyl-γ-methylenepyran is polymerized to a hexamer.

It has been found [1, 2] that 2,4,6-trimethylpyrylium perchlorate (I) does not form quaternary pyridinium salts with weakly basic heterocyclic amines. According to the calculations in [3, 4] by the Pariser–Parr–Pople (PPP) method, the positive charge in the ring of 2,4,6-triphenylpyrylium perchlorate (II) is lower than in I due to its partial (above 20%) delocalization over the phenyl substituents (see Table 1).

It was natural to assume that the number of amines that form quaternary pyridinium salts with perchlorate II will be still lower. However, it was found that almost all of the heterocyclic amines that we investigated react with perchlorate II in absolute dimethylformamide (DMFA) to give N-hetarylpyridinium salts (III):



II III a-o

III a R = 2-pyridyl; b R = 4-pyridyl; c R = 2-benzimidazolyl; d R = 1-methyl-2-benzimidazolyl; e R = 1-ethyl 2-benzimidazolyl; f R = 1-methyl-5-benzimidazolyl [2]; g R = 2-benzimidazolylmethyl [2]; h R = (2-benzimidazolyl)-2-ethyl [2]; i R = 1-methyl-5,6-diphenyl-2-imidazolyl; j R = 3-methylnaphth[1,2-d]-2-imidazolyl; k R = 6-bromo-2-benzothiazolyl; l R = 1,2,4-triazoly-3-yl; m R = 5-tetrazolyl; n R = 6-purinyl; o R = 2,4-dihydroxy-6-amino-5-pyrimidyl.

TABLE 1. Distribution of the Positive Charge Density in Perchlorates I and II

Compound	α, α′	β, β′	γ	O Atom
I	+0,210	+0,010	+0,260	+0,300
II	+0,324	−0,065	+0,142	+0,128

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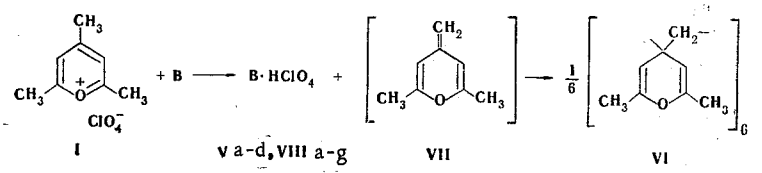
Intense absorption bands of the pyridinium ring at 1620-1637 and 1550-1580 cm^{-1} and of the perchlorate anion at 1100 cm^{-1} are present in the IR spectra of the compounds obtained.

The reaction of perchlorate II with 5,6-diaminouracil proceeds at one amino group. The starting materials are isolated in unchanged form only with guanine and N-aminocollidinium perchlorate. In the first case, the reaction does not proceed because of the low solubility of guanine, whereas in the second case the reaction does not proceed either because of steric hindrance or because of the very low basicity of the amino group.

It has been assumed [1, 2] that if perchlorate I does not form a quaternary pyridinium salt with heterocyclic amines, under the influence of air moisture it is converted to a 1,5-diketone, during which it loses a molecule of perchloric acid, which forms the perchlorate of the starting amine. However, we have observed that perchlorate I actually reacts with such amines to give the perchlorate of the starting amine (V), which is itself converted to a red compound, to which we assign structure VI:



I V a-d, VIII a-g VII VI

V a B = 2-aminopyridine; b B = 4-aminopyridine; c B = 2-aminobenzimidazole; d B = 1-ethyl-2-aminobenzimidazole; e B = 2-amino-3-methylnaphth[1,2-d]imidazole; f B = 3-amino-1,2,4-triazole; g B = adenine; VIII a B = benzimidazole; b B = pyridine; c B = N-(1-methyl-5-benzimidazolyl)collidinium perchlorate; d B = N-(1-methyl-5-benzimidazolyl)-2,4,6-triphenylpyridinium perchlorate.

The reaction evidently proceeds by means of proton transfer from the methyl group of the pyrylium ring to the heterocyclic nitrogen atom to give the perchlorate of the starting heterocycle (V) and 2,6-dimethyl-4-methylenepyran (VII). The lability of the hydrogen atoms in methyl groups of pyrylium salts is well known [5, 6]. In addition, the properties of pyran VII should recall those of fulvene, which is capable of undergoing rapid polymerization [7]. The molecular weight of VI is 728. From the results of thin-layer chromatography (TLC) (Al_2O_3, chloroform) it can be assumed that VI is an individual substance rather than a mixture of polymers with different numbers of links. It possibly has a cyclic structure consisting of six fragments. The IR spectrum of VI does not contain the characteristic absorption bands of the carbonyl group, which means the oxygen atom is in the pyran ring forming bonds of the ether type. The PMR spectrum contains a singlet at δ 6.80 ppm, which can be assigned to the signals of two identical $\rangle C{=}C\langle_{H}$ groups, two incompletely resolved singlets at δ 2.22 ppm (signals of $-CH_2-$ protons), and at δ 2.00 ppm (signals of $-CH_3$ groups). Moreover, the ratio of the overall intensities of the signals of the last two groups to the intensity of the signals of the protons of the first group is 8:2. Thus, on the basis of the PMR spectrum, it can be assumed that a proton is stripped from the γ-methyl group of perchlorate I.

Polymer VI reacts with 70% perchloric acid to give an unstable green compound, apparently of the oxonium type, which is rapidly reconverted to the starting red VI on attempts to filter it.

The participation of the pyridine nitrogen atom in the formation of the methylenepyran is confirmed by its occurrence in the reaction of perchlorate I with benzimidazole, during which the gradual formation of a red precipitate commences even in the cold. Under the same conditions, the reaction does not occur with perchlorate II, which does not contain methyl groups.

An analogous reaction of perchlorate I with excess pyridine is known [8]; Farcasiv and Gard isolated pyridinium perchlorate and postulated the formation of 2- or 4-methylenepyrans, which were not isolated. Perchlorate I was obtained again in low yield on treatment with acid. Despite the fact that Farcasiv and Gard record the appearance of the red color of the pyridine solution, they did not observe the VI that was formed, evidently because, as we found, it is quite soluble in pyridine and moderately soluble in ether.

In order to study the boundaries of the basicities of heterocyclic amines that react with pyrylium perchlorates via one or another mechanism, we measured the ionization constants of some of them in acetonitrile (Table 2). As seen from Table 2, we were able to measure only the constant of primary protonation, which sould be ascribed to the nitrogen atom in the ring (which is more basic than the amino group [12]), for all of the heterocyclic compounds except 1-methyl-5-aminobenzimidazole. Inasmuch as the basicities of the amino groups in nitrogen-containing heterocycles cannot be measured, the available litera-

TABLE 2. Ionization Constants of Amines and Results of Their Reaction with Pyrylium Salts I and II

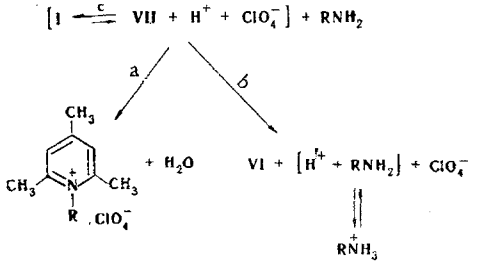
No.	Amine	pK_a (25 ± 0.1 deg C) acetonitrile	Result of the reaction*	
			with I	with II
1	4-Aminopyridine	17.61	b	a
2	1-Ethyl-2-aminobenzimidazole	16.22	b	a
3	2-Aminobenzimidazole	15.95	b	a
4	2-Amino-3-methylnaphth[1,2-d]imidazole	15.51	b	a
5	1-Methyl-5-aminobenzimidazole	15.29 (7.45)	a	a
6	2-Aminopyridine	14.43	b	a
7	2-Aminothiazole	12.98	a	a
8	3-Amino-1,2,4-triazole	12.74	b	a
9	p-Toluidine	11.25[10]	a	a
10	Aniline	10.57[10]	a	a
11	6-Bromo-2-aminobenzothiazole	10.58	a	a
12	N-(m-Aminophenyl)-2,4,6-triphenylpyridinium perchlorate	7.56[9]	a	–
13	N-(m-Aminophenyl)isoquinolinium perchlorate	7.46[9]	a	–
14	N-(m-Aminophenyl)-2-methyl-4,6-diphenylpyridinium perchlorate	7.43[9]	a	–
15	N-(p-Aminophenyl)isoquinolinium perchlorate	7.40[9]	a	–
16	N-(m-Aminophenyl)collidinium perchlorate	7.27[9]	a	–
17	N-(p-Aminophenyl)-2-methyl-4,6-diphenylpyridinium perchlorate	7.21[9]	a	–
18	N-(p-Aminophenyl)collidinium perchlorate	7.18[9]	a	–
19	N-(p-Aminophenyl)-2,4,6-triphenylpyridinium perchlorate	7.17[9]	a	–
20	p-Nitroaniline	6.21[10]	a	a
21	o-Nitroaniline	4.85[11]	–	a
22	2,4-Dinitroaniline	†	c	c

* Reaction results: a indicates the formation of a quaternary pyridinium salt, b indicates the formation of the perchlorate of the starting amine and VI, and c indicates no reaction; a dash means that the reaction was not studied.

† In view of its low value, the pK_a could not be determined.

ture pK_a values of various anilines, each of which forms quaternary pyridinium salts with perchlorates I and II [9, 13], are presented in the table for comparison. It is apparent from these data that the boundary of the basicity of the amino groups lies below 5 pK_a units, inasmuch as p-nitroaniline still reacts with perchlorates I and II, o-nitroaniline undergoes only 5% reaction, and 2,4-dinitroaniline does not undergo this reaction.

As already noted above, two competitive processes are observed in the reaction of perchlorate I with heterocyclic amines; equilibrium c, which is significantly shifted to favor perchlorate I, should exist in solution:



It is logical to assume that the proton will be retained either by the methylenepyran or by the heterocyclic amine, depending on their basicities, and the course of the process via paths a or b is thereby determined. However, it is known [14] that methylamine reacts with perchlorate I in the α position to give a quaternary pyridinium salt and a small amount of xylidine. As we have shown above, triethylamine in the same reaction is converted to the perchlorate, forming hexamer VI from the pyrylium salt. In addition, it was found [2] that 1-methyl-5-aminobenzimidazole reacts with pyrylium salt I to give N-(1-methyl-5-benzimidazolyl)collidinium perchlorate (VIIIc), its diperchlorate, and hexamer VI. Although we also established

TABLE 3. N-Hetaryl-2,4,6-triphenylpyridinium Perchlorates (III)

Compound	mp, °C (from ethanol)	Empirical formula	Found, %				Calc., %				Yield, %
			C	H	Cl	N	C	H	Cl	N	
IIIa	300—301[16,a]	$C_{28}H_{21}ClN_2O_4$	69,3	4,5	7,5	5,9	69,4	4,4	7,3	5,8	89
IIIb	230—231[16,a]	$C_{28}H_{21}ClN_2O_4$	69,5	4,4	7,7	5,7	69,4	4,4	7,3	5,8	88
IIIc	255[16,b]	$C_{30}H_{22}ClN_3O_4$	69,0	4,4	7,0	8,2	68,8	4,2	6,8	8,0	73
IIId	144—146[16]	$C_{31}H_{24}ClN_3O_4 \cdot H_2O$	66,7	4,9	6,3	7,7	66,9	4,7	6,4	7,6	36
IIIe	140—142[16]	$C_{32}H_{26}ClN_3O_4 \cdot H_2O$	67,5	5,1	6,0	7,5	67,4	4,9	6,2	7,4	32
IIIf	294[2,c]	$C_{31}H_{24}ClN_3O_4$	69,0	4,9	6,3	8,0	69,2	4,5	6,6	7,8	72
IIIg	202—203[2]	$C_{31}H_{24}ClN_3O_4$	69,5	4,7	6,2	7,9	69,2	4,5	6,6	7,8	68
IIIh	128[2]	$C_{32}H_{26}ClN_3O_4 \cdot 2H_2O$	65,8	5,0	6,2	7,4	65,4	5,1	6,0	7,1	83
IIIi	261	$C_{39}H_{30}ClN_3O_4$	73,6	5,2	5,6	7,0	73,2	4,7	5,5	6,6	75
IIIj	305[a]	$C_{35}H_{26}ClN_3O_4$	71,2	4,5	5,6	6,7	71,5	4,5	6,0	7,1	85
IIIk	222—223[a]	$C_{30}H_{20}BrClN_2O_4S$	57,8	3,5	4,9	4,1	58,1	3,3	5,7	4,5	83
IIIl	253—254	$C_{25}H_{19}ClN_4O_4$	62,9	4,4	7,0	12,0	63,2	4,0	7,5	11,8	92
IIIm	222[a]	$C_{24}H_{18}ClN_5O_4$	61,0	4,3	7,1	14,6	60,6	3,8	7,5	14,7	67
IIIn	307	$C_{28}H_{20}ClN_5O_4$	63,6	4,3	6,3	13,3	63,9	3,8	6,7	13,3	94
IIIo	327—328	$C_{27}H_{21}ClN_4O_6$	60,9	4,5	7,1	10,0	60,8	4,0	6,7	10,5	95

[a]From glacial acetic acid.
[b]From butanol.
[c]From methanol.

TABLE 4. Perchlorates of Heterocycles (V[a] and VIII)

Compound	mp, °C (from glacial acetic acid)	Empirical formula	Found, %				Calc., %				Yield, %
			C	H	Cl	N	C	H	Cl	N	
Va	182—183	$C_5H_6N_2 \cdot HClO_4$	30,7	3,9	18,0	14,7	30,9	3,6	18,2	14,4	56
Vb	271—272	$C_5H_6N_2 \cdot HClO_4$	30,9	4,0	18,3	14,8	30,9	3,6	18,2	14,4	56
Vc	197—198	$C_7H_7N_3 \cdot HClO_4$	36,4	3,8	15,0	18,4	36,0	3,5	15,2	18,0	56
Vd	119—120	$C_9H_{11}N_3 \cdot HClO_4$	41,1	4,9	13,3	16,4	41,3	4,6	13,6	16,1	70
Ve	259	$C_{12}H_{11}N_3 \cdot HClO_4$	48,6	4,4	11,4	13,9	48,4	4,1	11,9	14,1	84
VIIIa	194	$C_7H_6N_2 \cdot HClO_4$	38,7	3,3	16,0	12,9	38,5	3,2	16,2	12,8	91
VIIIb	288[9,b]	$C_5H_5N \cdot HClO_4$	33,3	3,5	19,5	8,0	33,4	3,4	19,7	7,8	71
VIIIc	278[2,c]	$C_{16}H_{18}ClN_3O_4 \cdot HClO_4$	42,9	4,6	15,3	9,4	42,5	4,2	15,7	9,3	79
VIIId	313[d]	$C_{31}H_{24}ClN_3O_4 \cdot HClO_4$	57,9	4,2	10,6	6,1	58,3	4,0	11,1	6,6	65

[a]3-Amino-1,2,4-triazolium (Vf) and adenine (Vg) perchlorates could not be purified, but the bases were isolated from them and identified.
[b]From ethanol.
[c]From methanol.
[d]From ethanol containing nitromethane.

that 1-methyl-5-aminobenzimidazole monoperchlorate reacts with I to give a quaternary pyridinium salt, the presence in the reaction mixture of VIIIc can be explained only by the fact that the reaction proceeds initially at the amino group rather than at the pyridine nitrogen atom (despite its greater basicity). In individual experiments we showed that VIIIc reacts with salt I to give a diperchlorate and hexamer VI. N-(1-Methyl-5-benzimidazolyl)-2,4,6-triphenylpyridinium perchlorate reacts with perchlorate I in a similar manner. Thus the heterocyclic amine attacks the pyrylium salt at both the α and γ positions, but if the most electrophilic oxygen can participate in the reaction, this reaction is the preferred one. Consequently, if the basicity of the heterocyclic amino group is sufficient, a quaternary pyridinium salt is formed (process *a*). However, if this basicity is considerably reduced, the reaction proceeds in the γ position to give a methylenepyran (process b). In fact, heterocyclic amines in which, owing to the substantial contribution of the charged resonance form with a positive charge on the nitrogen atom of the amino group, the basicity of the latter is lower, react via path b:

Process *a* is realized with 1-methyl-5-aminobenzimidazole, in which a charged resonance form is impossible. 2-Aminothiazole and its benzo derivative, for which the elevated basicity of the amino group is explained by the effect of the adjacent sulfur atom, also react via path *a*. Unfortunately, this boundary of the basicity of the amino groups cannot be quantitatively evaluated.

The reaction of perchlorate I with heterocyclic amines in glacial acetic acid does not proceed with

all amines. However, when the reaction is carried out in dimethylformamide (DMFA), a green-violet oil is formed along with the indicated products; this oil is a mixture of products of condensation of DMFA at the methyl groups of perchlorate I, which we were unable to separate and purify.

Pyrylium salt I does not react with N-aminocollidinium [1], N-(o-aminophenyl)collidinium [9], and N-(o-aminophenyl)isoquinolinium [9] perchlorates or guanine, apparently for the same reason as in the case of perchlorate II.

EXPERIMENTAL

The pK_a values were measured by potentiometric titration in absolute acetonitrile by the method in [15] at 25 ± 0.1°. The IR spectra of mineral oil suspensions of the compounds were recorded with a UR-20 spectrometer. The PMR spectrum of a methylene chloride solution was measured with a BS487c spectrometer (80 MHz) with hexamethyldisiloxane as the internal standard. The molecular weight was determined cryoscopically in benzene.

The N-hetaryl-2,4,6-triphenylpyridinium perchlorates (III) were obtained by refluxing the amine and perchlorate II in a ratio of 1.2 : 1 in absolute DMFA for 1 h. They were precipitated from the reaction mixture with ether. Data on III are presented in Table 3.

Reaction of Perchlorate I with 2-Aminobenzimidazole. A mixture of 0.67 g (5 mmole) of 2-aminobenzimidazole and 1.11 g (5 mmole) of perchlorate I was refluxed in 10 ml of glacial acetic acid for 1 h. Cooling of the mixture precipitated 0.35 g (57%) of red VI, which melted above 350° (dec.) after purification with a chromatographic column filled with Al_2O_3 (elution with chloroform). Found, %: C 78.6; H 8.0. $C_{48}H_{60}O_6$. Calculated, %: C 78.6; H 8.3. The addition of ether to the filtrate precipitated 0.65 g (56%) of 2-aminobenzimidazolium perchlorate (see Table 4). The reaction of salt I with 4-aminopyridine was carried out similarly; the reaction with the remaining amines occurred under the same conditions but in absolute DMFA. The yield of polymer VI was 40-60%. Data on the perchlorates of heterocyclic amines obtained in this research are presented in Table 4. The reaction of perchlorate I with benzimidazole, pyridine, and N-(1-methyl-2-benzimidazolyl)-2,4,6-triphenylpyridinium and collidinium perchlorates was carried out similarly in alcohol, glacial acetic acid, or DMFA. The yield of VI was 43-91%. Data on the perchlorates of the starting heterocycles are presented in Table 4.

N-(p-Nitrophenyl)collidinium Perchlorate. A 2.23-g (0.01 mole) sample of perchlorate I and 2.08 g (0.015 mole) of p-nitroaniline were refluxed in 8 ml of glacial acetic acid for 3.5 h. The mixture was then cooled, and the precipitated collidinium perchlorate was removed by filtration. An additional amount of the collidinium perchlorate was precipitated from the filtrate by the addition of ether. In order to remove unchanged perchlorate I, the product was dissolved by heating in the minimum amount of ethanol, ammonium hydroxide was added, and the collidine that formed in the reaction stayed in solution. The solution was then cooled and filtered to give 1.05 g of a colorless precipitate with mp 248° (from water). The yield was 62%. Found, %: C 49.1; H 4.8; Cl 10.9; N 8.3. $C_{14}H_{15}ClN_2O_6$. Calculated, %: C 49.1; H 4.4; Cl 10.4; N 8.2.

N-(p-Nitrophenyl)-2,4,6-triphenylpyridinium Perchlorate [16]. This compound was obtained in 85% yield by the reaction of perchlorate II with p-nitroaniline in absolute DMFA by a method similar to that used to obtain III.

N-(o-Nitrophenyl)-2,4,6-triphenylpyridinium Perchlorate. This compound was obtained in 5% yield by reaction of perchlorate II with o-nitroaniline under the same conditions and had mp 149-150° (from ethanol). Found, %: C 65.7; H 4.2; Cl 6.5; N 5.3. $C_{29}H_{21}ClN_2O_6$. Calculated, %: C 65.8; H 4.0; Cl 6.7; N 5.3.

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