

FERRICYANIDE OXIDATION OF 1-SUBSTITUTED PENTAPHENYLPYRIDINIUM SALTS. A NOVEL ROUTE TO 1-SUBSTITUTED 2,3,4,5-TETRAPHENYLPYRROLES

Stanislav BÖHM, Hanuš SLAVÍK and Josef KUTHAN

Department of Organic Chemistry,

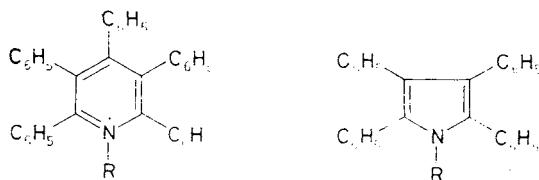
Prague Institute of Chemical Technology, 166 28 Prague 6

Received February 9, 1988

Accepted February 16, 1988

Oxidation of 1-substituted 2,3,4,5,6-pentaphenylpyridinium salts *Ia–Ij* by potassium ferricyanide in an alkaline medium yields the corresponding 1-substituted 2,3,4,5-tetraphenylpyrroles in 68 to 76% yields. The selectivity of the reaction is discussed.

The contraction of the pyridine to pyrrole ring is typical feature of the ferricyanide oxidation of the quarternary pyridinium salts substituted by phenyl or tert. butyl groups^{1–4} in positions 2, 4 and 6. If the starting pyridinium salt has an additional substituent in position 3, the oxidation can proceed by two reaction paths, yielding pyrrole derivatives of alternative structures⁴. In relation to these findings, another extension of the application of the ferricyanide oxidation to the fully substituted substrates *I* can be envisaged. This should lead to the fully substituted products, 1-alkyl or 1-aryl-2,3,4,5-tetraphenylpyrroles *II*. Justification of this conclusion is



Ia, R = CH₃.

Ib, R = C₆H₅.

Ic, R = C₆H₁₃.

Ia', R = *n*-C₆H₁₃.

Ie, R = C₆H₅.

If, R = *p*-CH₃C₆H₄.

Ig, R = *p*-CH₂OC₆H₅.

Ih, R = *p*-CH₂CH₂OC₆H₅.

Ii, R = C₆H₅CH₂.

Ij, R = 2-pyridyl

IIa, R = CH₃.

IIb, R = C₆H₅.

IIc, R = C₆H₁₃.

IIa', R = *n*-C₆H₁₃.

IIe, R = C₆H₅.

IIf, R = *p*-CH₃C₆H₄.

IIg, R = *p*-CH₂OC₆H₅.

IIh, R = *p*-CH₂CH₂OC₆H₅.

IIi, R = C₆H₅CH₂.

IIj, R = 2-pyridyl

documented experimentally in the present work by transformation of ten quarternary pyridinium salts *Ia–Ij* to the corresponding pyrrole derivatives *IIa–IIj*.

Methods for preparing compounds of the type *II* have so far been based on different principles. Compounds *IIa* and *IIb* were prepared⁵ by cyclocondensation of 1,2,3,4-pentaphenyl-1,4-butadione with methylamine or ethylamine at higher temperatures. 1-Phenyl derivative *IIe* is obtained⁶ either by the reaction of 2,3,4,5-tetraphenyl-2,4-cyclopentadiene-1-one with nitro- or nitrosobenzene, or by treating benzene ammonium chloride with 2,3,4,5-tetraphenylfuran at high temperatures (400°C). Pyrrole derivatives *IIa* and *IIe–IIg* were obtained⁷ by the reduction of 1-substituted 3,3,4,5-tetraphenyl-3,4-dihydro-2-oxopyrroles with lithium aluminium hydride. 1-Methyl derivative *IIa* and 1-benzyl derivative *IIIi* are available also via alkylation of 2,3,4,5-tetraphenylpyrrole obtained from deoxybenzointetrazine⁸ or by the reaction of 1-lithio-1,2-diphenylethylimine with diphenylethyne⁹. The last mentioned hydrocarbon can be also used to prepare 1-methyl derivative *IIa* by the different, less clear procedures.¹⁰

The starting quarternary pyridinium salts *Ia–Ij* were obtained from the readily available¹¹ pentaphenylpyrylium bromide by its reaction with corresponding primary amines. With the more nucleophilic aliphatic amines the reaction proceeds at sufficiently fast rate already at room temperature, while with the less nucleophilic aromatic amines the acceptable degree of conversion is achieved only at higher temperatures after several hours (cf. Table I).

Similarly to the reaction of 2,4,6-triphenylpyridinium salts¹, the ferricyanide oxidation of salts *Ia–Ij* proceeds with high selectivity, affording 1-substituted 2,3,4,5-tetraphenylpyrroles *IIa–IIj* in high yields (cf. Table II). This allows us to conclude that we deal here apparently with a general preparative method suitable also for derivatives with other variations of substituents in position 1. In connection with the above fact, the selective transformation of 1-(2'-pyridyl) derivatives is remarkable, since the oxidation of 1-(2'-pyridyl)-2,4,6-triphenylpyridinium is accompanied by extension of the pyridine ring to the seven-membered one, giving the heterocyclic derivative *IIIa* (ref.³). In agreement with the postulated³ mechanism of ferricyanide oxidation one can assume that the contraction or extension of the pyridine ring is affected in general by mutual isomerization of the transiently formed cations *IV* and *V*. In the case of $R = H$ it seems likely that formation of the larger π -electron system ($V \rightarrow IV$) is energetically more favourable, and the bicyclic cation *IV* is then stabilized by deprotonation ($IV + OH^- \rightarrow IIIa + H_2O$). On the other hand, in the case of $R = C_6H_5$, formation of the ion *IV* is not energetically favourable from steric reasons ($IV \rightarrow V$), and the monocyclic ion *V* formed is stabilized here by debenzoylation ($V + OH^- \rightarrow IIj + C_6H_5CO_2H$). In favour of this interpretation speaks also the earlier found⁴ debenzoylation course, which in the case of formation of the bicyclic ion *IV* ($R = C_6H_5$) would inevitably lead to compound *VI* which is isomeric with the pyrrole derivative *IIj*. Also this possibility was excluded by com-

TABLE I
Quarternary pyridinium salts *Ia*–*Ij*

Compound	Reaction time, h (yield, %)	M.p., °C (solvent)	Formula (M.w.)	Calculated/Found				δ , ppm ^a
				% C	% H	% N	% Br	
<i>Ia</i>	24 (78)	277 (C ₂ H ₅ OH)	C ₃₆ H ₂₈ NBr (554.5)	77.97	5.09	2.53	14.41	6.89–7.85 m (arom. H), 3.82 s (CH ₃)
				77.72	5.09	2.63	14.60	
<i>Ib</i>	24 (80)	278–280 ^b (CH ₃ OH)	C ₃₇ H ₃₀ NBr (568.6)	78.17	5.32	2.46	14.05	6.88–7.84 m (arom. H), 1.23 t (CH ₃), 4.43 q (CH ₂)
				78.01	5.31	2.61	13.85	
<i>Ic</i>	24 (85)	270–272 (CH ₃ OH)	C ₃₈ H ₃₂ NBr (582.6)	78.34	5.54	2.40	13.72	6.88–7.74 m (arom. H), 0.35 t (CH ₃), 1.76 sex, 4.23 t (CH ₂)
				78.38	5.51	2.63	13.64	
<i>Id</i>	24 (81)	295–297 ^c (CH ₃ OH)	C ₃₉ H ₃₄ NBr (596.6)	78.52	5.74	2.35	13.39	6.82–7.45 m (arom. H), 0.48 t (CH ₃), 0.82 sex, 1.21 qui, 3.37 t (CH ₂)
				78.66	5.80	2.34	13.18	
<i>Ie</i>	10 ^d (96)	over 360 (HCOOH)	C ₄₁ H ₃₀ NBr (616.5)	79.86	4.90	2.27	12.96	6.81–7.41 m (arom. H)
				80.04	4.88	2.39	13.00	
<i>If</i>	10 ^d (84)	over 360 (HCOOH)	C ₄₂ H ₃₂ NBr (630.6)	79.99	5.11	2.22	12.67	6.77–7.43 m (arom. H), 2.05 s (CH ₃)
				80.13	5.13	2.34	12.85	
<i>Ig</i>	10 ^d (88)	over 360 (HCOOH)	C ₄₂ H ₃₂ NBrO (646.6)	78.01	4.99	2.17	12.36	6.46–7.58 m (arom. H), 3.55 s (CH ₃)
				77.90	5.01	2.22	12.19	
<i>Ih</i>	10 ^d (83)	over 360 (HCOOH)	C ₄₃ H ₃₄ NBrO (660.7)	78.18	5.19	2.12	12.09	6.47–7.56 m (arom. H), 1.15 t (CH ₃), 3.71 q (CH ₂)
				78.17	5.26	2.06	12.20	
<i>Ii</i>	8 ^d (86)	249–250 ^e (CH ₃ OH)	C ₄₂ H ₃₂ NBr (630.5)	79.99	5.11	2.22	12.67	6.66–7.27 m (arom. H), 5.71 s (CH ₂)
				79.91	5.14	2.28	12.50	
<i>Ij</i>	10 ^d (79)	over 360 ^f (CH ₃ OH)	C ₄₀ H ₂₉ N ₂ Br (617.5)	77.79	4.73	4.54	12.94	6.89–8.30 m (arom. H)
				77.88	4.62	4.50	12.81	

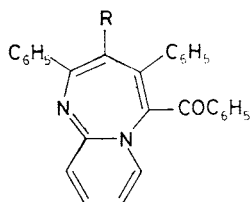
^a t triplet, q quartet, qui quintet, sex sextet, m multiplet; ^b ref.¹¹ 280°C; ^c ref.¹¹ 287°C; ^d reflux; ^e ref.¹¹ 247°C; ^f ref.¹¹ 300°C.

TABLE II
1-Substituted 2,3,4,5-tetraphenylpyrroles *IIa*—*IIj*

Compound	Reaction time, h (yield, %)	M.p. °C	Formula (M.w.)	Calculated/Found			δ , ppm ^a
				% C	% H	% N	
<i>IIa</i>	20 (69)	210—211 ^b	C ₂₉ H ₂₃ N (385.5)	90.35 90.05	6.01 6.10	3.63 3.50	6.95—7.32 m (arom. H), 3.44 s (CH ₃)
<i>IIb</i>	20 (70)	217—218 ^c	C ₃₀ H ₂₅ N (399.5)	90.18 90.24	6.31 6.45	3.51 3.33	6.91—7.33 m (arom. H), 0.97 t (CH ₃), 3.89 q (CH ₂)
<i>IIc</i>	20 (68)	179—180	C ₃₁ H ₂₇ N (413.6)	90.03 89.95	6.58 6.78	3.39 3.33	6.92—7.32 m (arom. H), 0.57 t (CH ₃), 1.38 sex, 3.77 t (CH ₂)
<i>II d</i>	20 (68)	179—180	C ₃₂ H ₂₉ N (427.6)	89.89 89.85	6.84 7.02	3.27 3.35	6.92—7.37 m (arom. H), 0.61 t (CH ₃), 0.98 sex, 1.35 qui, 3.80 t (CH ₂)
<i>IIe</i>	30 (76)	280—282 ^d	C ₃₄ H ₂₅ N (447.5)	91.24 90.97	5.63 5.75	3.13 3.12	6.80—7.36 m (arom. H)
<i>II f</i>	30 (75)	272—273 ^e	C ₃₅ H ₂₇ N (461.6)	91.08 90.87	5.89 6.05	3.03 3.08	6.79—7.24 m (arom. H), 2.25 s (CH ₃)
<i>II g</i>	30 (69)	272—273 ^f	C ₃₅ H ₂₇ NO (477.6)	88.02 88.10	5.70 5.85	2.93 2.83	6.63—7.41 m (arom. H), 3.72 s (CH ₃)
<i>II h</i>	30 (73)	234—235	C ₃₆ H ₂₉ NO (491.6)	87.95 87.83	5.95 5.86	2.85 2.94	6.62—7.36 m (arom. H), 1.37 t (CH ₃), 3.93 q (CH ₂)
<i>II i</i>	20 (71)	218—219 ^g	C ₃₅ H ₂₇ N (461.6)	91.08 90.89	5.89 6.01	3.03 2.96	6.95—7.25 m (arom. H), 5.07 s (CH ₂)
<i>II j</i>	30 (70)	266—267	C ₃₃ H ₂₄ N ₂ (434.6)	88.36 88.10	5.39 5.47	6.25 6.34	6.89—8.30 m (arom. H)

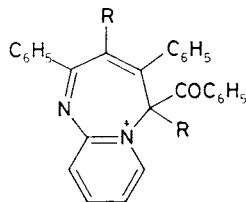
^a For designation see note *a* in Table I; ^b ref.⁵ 214°C, ref.⁸ 210°C, ref.⁹ 210°C, ref.¹⁰ 209—211°C; ^c ref.⁵ 221°C; ^d ref.⁶ 282°C; ^e ref.⁷ 270 to 271°C; ^f ref.⁷ 270—271°C; ^g ref.⁹ 218°C.

parison of spectral characteristics of the earlier prepared³ compound *IIIa*. Comparison of UV spectra of substances *II* shows that the compound *IIj* have similar characteristics ($\lambda_{\max} = 255 \text{ nm}$) as other pyrrole derivatives *IIa–IIi* but differs markedly from the compound *IIIa* (ref.³). This fact can be taken as sufficient argument for the molecular structure *IIj* assigned by us to the product of ferricyanide oxidation of the quarternary salt *Ij*.

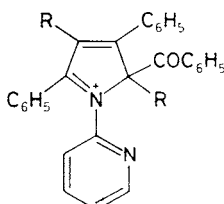


IIIa, R = H

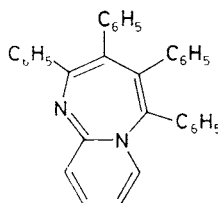
IIIb, R = C₆H₅



IV



V



VI

EXPERIMENTAL

Temperature data are uncorrected, NMR spectra were measured on Bruker AM 400 spectrometer, using deuteriochloroform as the solvent and tetramethylsilane as the internal reference.

Synthesis of N-Substituted 2,3,4,5,6-Pentaphenylpyridinium Bromides *Ia–Ij*

A total of 1.5 molar excess of a primary amine was added to a suspension of 3.0 g (5.54 mmol) of 2,3,4,5,6-pentaphenylpyrylium bromide in 40 ml of methanol. Aliphatic amines were stirred at room temperature overnight, aromatic amines were refluxed. The crystals so formed were filtered with suction and recrystallized (ethanol, methanol, acetic acid, formic acid, always with addition of small amounts of aqueous hydrogen bromide, except for compound *Ij*). Details concerning these reactions, elemental analyses and ¹H NMR spectra of compounds *Ia–Ij* are presented in Table I.

Oxidation of Salts *Ia–Ij*

A total of 4.0 g (0.012 mol) of potassium ferricyanide and 2.0 g (0.036 mol) of potassium hydroxide dissolved in 40 ml of water were added to a suspension of 3.3 mmol (~2 g) of 1-substi-

tuted 2,3,4,5,6-pentaphenylpyridinium salt *I* in 100 ml of ethanol. The mixture was refluxed with stirring. After the reaction had been completed, 250 ml of water were added and the product was extracted thrice with 100 ml-portions of chloroform. The organic layer was washed with water, dried over calcium chloride (potassium carbonate for compound *IIj*), the chloroform was evaporated and the raw product was recrystallized from benzene-hexane (2 : 1) — compounds *Iib*, *Iic*, *Iig*, *Iih*, *Iij* or from benzene — compounds *Iie*, *Iif*, *Iii*. Compounds *Iia* and *Iid* were purified by column chromatography (SiO₂, CHCl₃). Characteristics of the reactions, elemental analyses and ¹H NMR spectra are presented in Table II.

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Translated by J. Hetflejš.