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RADIATION-INDUCED REACTIONS OF PYRIDINECARBOXYLIC ACID ESTERS IN ACIDIC ALCOHOLIC SOLUTIONS.

SUBSTITUTION BY ALKYL AND HYDROXYALKYL GROUPS AND REDUCTION OF CARBOXYLIC ESTER TO ALCOHOL

Kazuhito NAKAMURA, Toru SUGIYAMA, Toru SUZUKI, and Akira SUGIMORI
Department of Chemistry, Faculty of Science and Technology,
Sophia University, Kioi-cho 7, Chiyoda-ku, Tokyo 102

The main reactions of pyridinecarboxylic acid esters induced by Co-60 γ-rays are 1) substitution on the pyridine ring by alkyl or hydroxyalkyl groups derived from solvent alcohols and 2) the reduction of carboxylic esters to alcohols (hydroxymethyl group). Substitution is dominant in methanol solutions and reduction is dominant in 2-propanol solutions.

In contrast to extensive studies on photochemical reactions of pyridine derivatives,[1] the behavior of pyridine derivatives toward ionizing radiation has not yet been thoroughly investigated in other than aqueous solutions.[2] In comparison with the photochemical reactions[3] the radiation-induced reactions of pyridinecarboxylic acid esters in acidic alcoholic solutions are investigated.

Alcoholic solutions of pyridinecarboxylic acid esters (0.03 mol dm^{-3}) acidified with sulfuric acid (0.05 mol dm^{-3}) and saturated with nitrogen by bubbling N_2 for at least 30 minutes were irradiated with Co-60 γ-rays at a dose rate of 5×10^5 rad h^{-1} for 20 h. After the irradiated solutions were concentrated and neutralized, the products were separated by means of thin layer chromatography. The products were identified by the comparison with authentic samples and spectroscopically by means of IR and NMR. Quantitative analyses were carried out gravimetrically or gas-chromatographically.

The main reactions are: 1) the substitution on the pyridine ring by alkyl and/or hydroxyalkyl groups which originates from the solvent alcohols and 2) the reduction of the alkoxycarbonyl group to hydroxymethyl group.

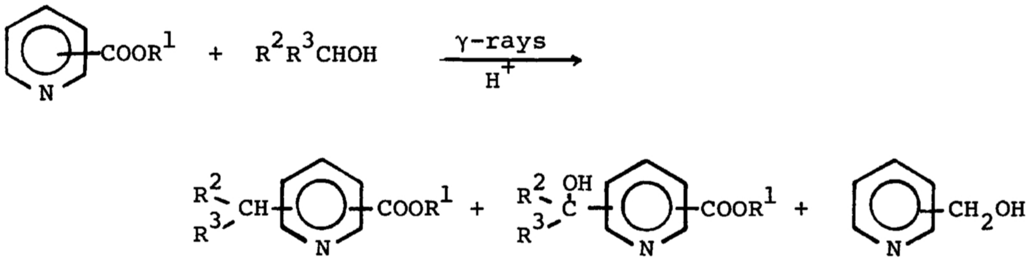


Table 1 Radiation-induced substitution of alkyl pyridinecarboxylates

Substrate	Alcohol	Substitution product	G-value
Methyl 2-pyridinecarboxylate	MeOH	4-Me	1.29
		4,6-diMe	0.10
		4-Me-6-$HOCH_2$	0.16
Ethyl 2-pyridinecarboxylate	EtOH	4-Et	0.12
		6-Et	0.01
Butyl 2-pyridinecarboxylate	BuOH	4-Bu	0.10
		6-Bu	0.08
i-Propyl 2-pyridinecarboxylate	i-PrOH	6-i-Pr	0.02
Methyl 3-pyridinecarboxylate	MeOH	6-Me	0.58
		4-Me	0.21
		4,6-diMe	0.31
Ethyl 3-pyridinecarboxylate	EtOH	6-Et	1.42
Methyl 4-pyridinecarboxylate	MeOH	2-Me	0.16
		2-$HOCH_2$	0.23
Ethyl 4-pyridinecarboxylate	EtOH	2-$HOCH_2CH_2$	0.03

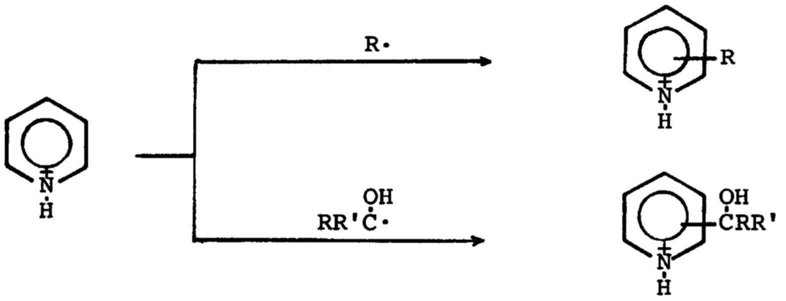
Table 2 Dependence of G-values for reduction of alkyl 2-and 4-pyridinecarboxylates to 2- and 4-hydroxymethylpyridines on alcohol

Substrate	Alcohol	G(Hydroxymethylpyridine)
Methyl 2-pyridinecarboxylate	MeOH	0.012
	EtOH	0.54
	PrOH	0.46
	BuOH	0.40
	i-PrOH	0.93
Ethyl 4-pyridinecarboxylate	EtOH	0.13

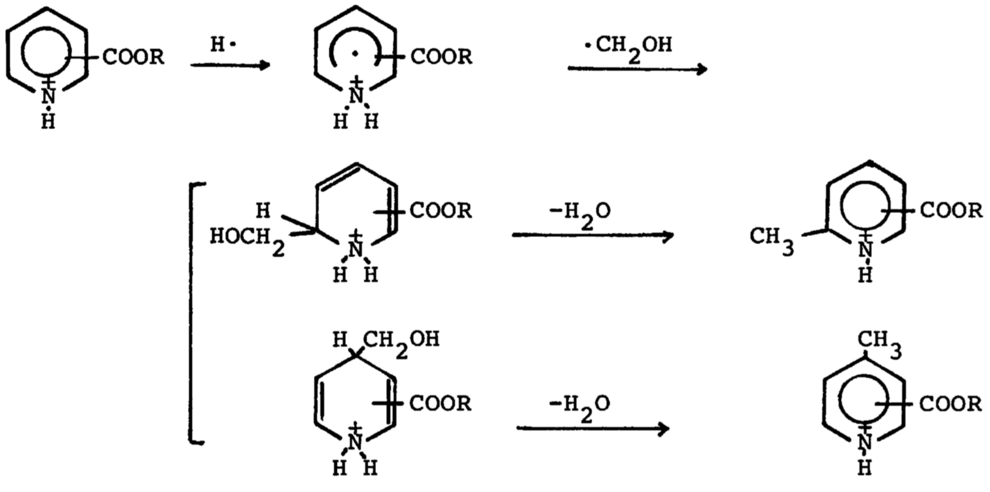
Results are summarized in Table 1 and 2. Substitution occurs selectively at the 2-, 4-, and 6- positions of the pyridine ring, regardless of the position of alkoxycarbonyl group.

Substitution and reduction are competitive as exemplified in the reaction of methyl 2-pyridinecarboxylate. In methanol solutions, substitution is predominant, whereas in 2-propanol solutions, reduction is predominant. The fact that substitution and reduction are depressed by radical scavengers, such as iodine, iron(III) chloride, and iron(III) sulfate, suggests that the both reactions proceed via free radical mechanisms.

Free radical substitution of pyridinium compounds has been investigated by Minisci and coworkers.[4)] According to them, alkyl radicals bring about alkylation and hydroxyalkyl radicals, hydroxyalkylation.



Reported G-values for primary reactive species from methanol are 2.0 for electron, 1.1 for H·, 0.2 for ·OH, 0.2 for CH_3·, and 2.7 for ·CH_2OH.[5)] The fact that alkylation is favored over hydroxyalkylation is not consistent with the higher G-value of ·CH_2OH and lower G-value of CH_3·. Therefore, a free radical mechanism in which hydrogen atoms participate should be considered.



It is interesting that in the ethyl 4-pyridinecarboxylate-ethanol system, not α-hydroxyethyl but β-hydroxyethyl product was confirmed.

The other important reaction is the reduction of the alkoxycarbonyl group to hydroxymethyl group. As the reducing species, hydroxyalkyl radicals and hydrogen atoms should be taken into consideration. Solvated electrons can not participate in the reduction, because they react with H^+ rather than with substrates to give hydrogen atoms. The fact that the reduction is dependent on the solvents suggests that the reducing species are hydroxyalkyl radicals. The series of $E_{1/2}$ vs. SCE6) -1.30 V ($CH_3\dot{C}(OH)CH_3$), -1.18 V ($CH_3\dot{C}HOH$), and -0.98 V ($\cdot CH_2OH$) correlates well with the G-values for reduction. Aldehydes, which could be postulated as intermediates for the reduction of alkoxycarbonyl groups, were not found in the irradiated solutions. Furthermore, the irradiation of 2-pyridinecarbaldehyde in ethanol gave only a small amount of 2-hydroxymethylpyridine.

Sunlight-irradiation of the pyridinecarboxylic esters-ethanol-acetone system gave reduction products but no alkylated products. In this system, where exist hydroxyalkyl radicals ($CH_3\dot{C}HOH$ and $CH_3\dot{C}(OH)CH_3$), which are formed in the hydrogen abstraction by the excited acetone from ethanol, but no hydrogen atoms. This fact supports the above proposed mechamism for substitution and reduction.

A small yield of reduction product in aqueous solutions show that hydrogen atoms also contribute to the reduction, although it does not play an important role.

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