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SUBSTITUTION OF ALKYL AND HYDROXYALKYL GROUP FOR RING HYDROGEN AND OF HYDROXYALKYL GROUP FOR CYANO GROUP IN GAMMA-IRRADIATION OF PYRIDINECARBONITRILES IN ALCOHOL

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Gamma-irradiation of pyridinecarbonitriles in alcohol in the presence of sulfuric acid brings about the substitution of the alkyl group derived from alcohol for the ring hydrogen, while that in the absence of sulfuric acid causes the substitution of hydroxyalkyl group for CN at the 2- and 4-positions. Hydroxyalkyl radicals and solvated electrons play important role in the substitution.

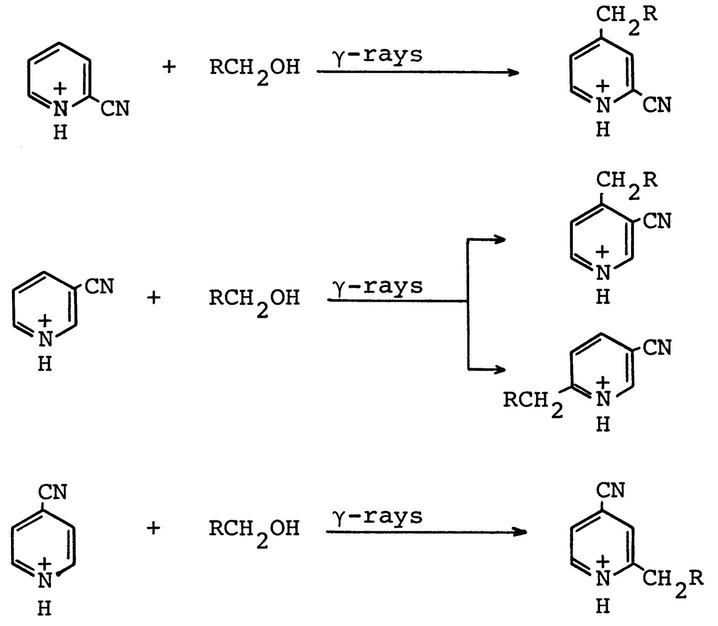
As a method to generate free radical species, the irradiation with ionizing radiation is advantageous over thermolysis and redox processes: 1) the irradiation with ionizing radiation can produce free radicals without coming under the influences of initiators and their products which may trap, oxidize, or reduce the free radical species and 2) the formation of free radical species can be performed at lower temperatures.

As an extension of our studies on the radiation-induced reactions of pyridinecarboxylic esters[1)] and pyridinecarboxamides[2)] we report here the γ-ray-induced reactions of pyridinecarbonitriles and compare them with the reactions initiated by UV-irradiation and by the thermolysis of peroxides.

The alcoholic solutions (for the irradiation in the presence of sulfuric acid, [nitrile] = 0.06 mol dm^{-3}, [H_2SO_4] = 0.3 mol dm^{-3}, deaerated with Ar; for the irradiation in the absence of sulfuric acid, [nitrile] = 0.03 mol dm^{-3}, deaerated and saturated with Ar or N_2O) were irradiated with Co-60 γ-rays at the Japan Atomic Energy Research Institute in Takasaki at a dose rate of 5×10^5 rad h^{-1} for 20 h (1 rad = 10^{-2}Gy = 10^{-2}J kg^{-1}).

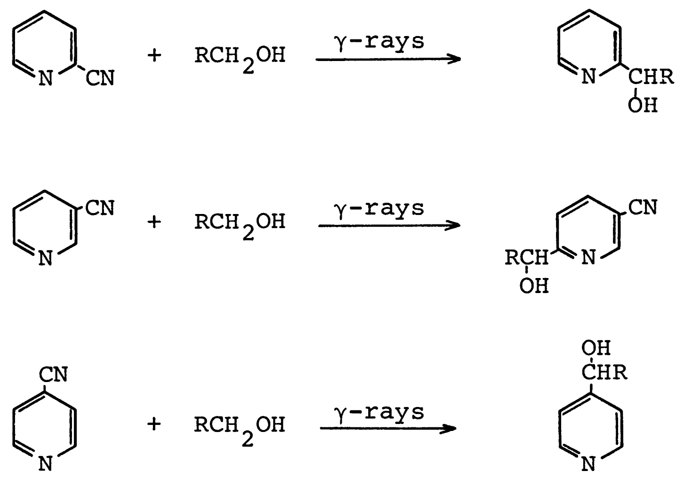
The radiation-induced reactions of pyridinecarbonitriles are dependent on the presence or absence of added mineral acid (in this case, sulfuric acid); the reactions of protonated forms of pyridinecarbonitriles are different from those of non-protonated forms.

Gamma-irradiation of pyridinecarbonitriles in the presence of sulfuric acid in methanol or in ethanol under Ar atmosphere brings about the replacement of the ring hydrogen at α- and γ-positions of the pyridine ring by the alkyl groups derived from the alcohol in comparatively high radiation-chemical yields (G-value= Number of product molecules/100 eV of radiation energy absorbed by the system).



	G-value
R = H,	0.86
$R = CH_3$,	0.20
R = H,	1.27
R = H,	1.15
R = H,	1.60
$R = CH_3$,	0.39

In the absence of sulfuric acid, γ-irradiation brings about the substitution of CN group at the 2- and 4-positions by hydroxyalkyl groups derived from alcohols.



	G-value	
	under Ar	under N_2O
R = H,	0.15	0.14
$R = CH_3$,	0.14	0.16
R = H,	0.06	0.06
$R = CH_3$,	0.05	0.09
R = H,	0.37	0.35
$R = CH_3$	0.31	0.31

Among free radical species formed in the radiolysis of alcohol, the solvated electron, hydrogen atom, and hydroxyalkyl radical should play important roles (in the case of methanol; G(solvated electron) = 2.0, G(H·) = 1.1, G(·CH_2OH) = 2.7, G(·CH_3) = 0.2, and G(·OH) = 0.2[3]). In the radiation-induced reaction in the presence of sulfuric acid, hydroxyalkyl radical is the sole reactive species, because the solvated electron reacts rapidly with H^+ to give ·H, and ·H abstracts a hydrogen atom from alcohol to give a hydroxyalkyl radical.

The radiation-induced reaction in the absence of sulfuric acid under N_2O

is also attributed to the reaction of $R\dot{C}HOH$, because the solvated electron reacts with N_2O to give $\cdot OH$, which abstracts hydrogen from alcohol to give hydroxyalkyl radical ($e^-_{solv} + N_2O + H^+ \longrightarrow \cdot OH + N_2$; $\cdot OH + RCH_2OH \longrightarrow R\dot{C}HOH + H_2O$).

In order to confirm the importance of the role of hydroxyalkyl radicals in the radiation-induced substitution, we investigated the system in which hydroxyalkyl radicals can be formed. The reactions of 4-pyridinecarbonitrile with hydroxyethyl radical generated by several methods are compared with the reactions induced by ionizing radiation.

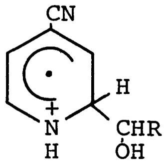
One of the methods to generate hydroxyethyl radical is via the hydrogen abstraction by photochemically excited acetone from ethanol. The UV-irradiation of an ethanolic solution of 4-pyridinecarbonitrile (0.01 mol dm^{-3}) with a medium pressure mercury lamp in the presence of acetone (2 mol dm^{-3}) gave 2-ethyl-4-pyridinecarbonitrile (2% yield) in acidic condition ([H_2SO_4] = 0.3 mol dm^{-3}) and 1-(4-pyridyl)ethanol (40% yield) in neutral condition.4)

Thermolysis of t-butyl peroxypivalate in ethanol at 75 °C in the presence of 4-pyridinecarbonitrile ([nitrile] = 0.06 mol dm^{-3}; [peroxide] = 0.12 mol dm^{-3}; reaction time, 4 h) also gave 2-ethyl-4-pyridinecarbonitrile (65% yield) in the presence of sulfuric acid ([H_2SO_4] = 0.3 mol dm^{-3}). Thermolysis of t-butyl peroxypivalate in the absence of sulfuric acid ([nitrile] = 0.06 mol dm^{-3}; [peroxide] = 0.10 mol dm^{-3}; reaction temperature, 75 °C; reaction time, 4.5 h) gave 1-(4-pyridyl)ethanol (5% yield).

These results support the important role of hydroxyalkyl radicals in the substitution reactions in pyridinecarbonitriles.

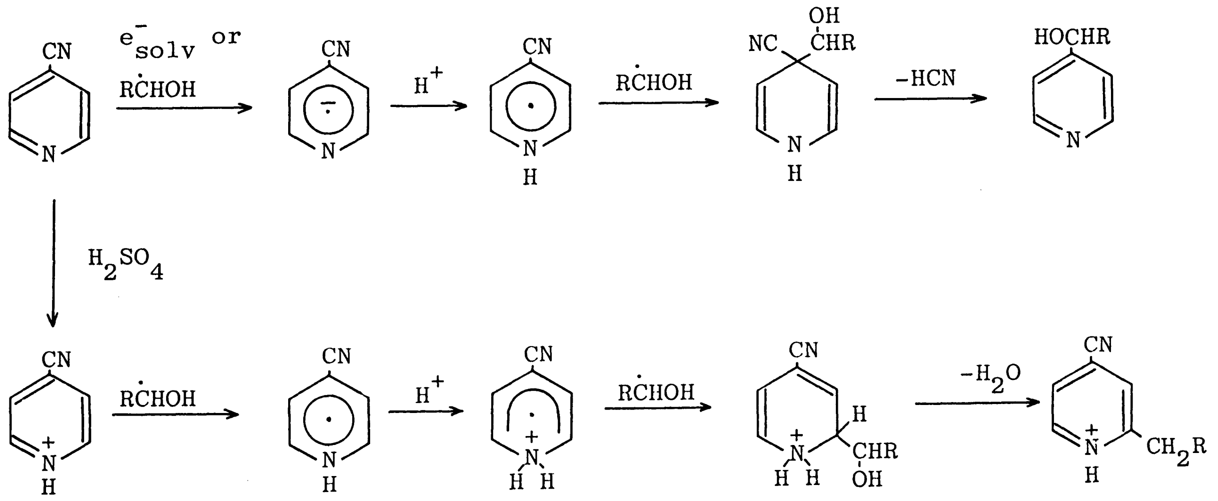
The fact that the radiation-induced reactions of pyridinecarbonitriles under Ar in the absence of sulfuric acid are similar to those under N_2O, with respect to the structures of the products and their radiation chemical yields, indicates that the solvated electron and hydroxyalkyl radical should play a common role in at least one step of the substitution reactions. The electron transfer should be postulated as the common process.5) Because efficient successive processes of electron transfer and proton transfer have been reported from $CH_3\dot{C}(OH)CH_3$ to pyridine derivatives,6) the radiation-induced substitution of CN by hydroxyalkyl groups should proceed in the mechanism shown in Scheme 1.

The alkylation by hydroxyalkyl radicals in the presence of sulfuric acid can be explained by a mechanism initiated by the electron transfer from hydroxyalkyl radicals to the protonated pyridine carbonitriles. The mechanism is shown in Scheme 1, as exemplified by the reaction of 4-pyridinecarbonitrile. An S_R2 mechanism should not operate, because the addition of hydroxyalkyl radical to the protonated substrate should result in hydroxyalkylation instead of alkylation via the disproportionation of the intermediate **Q** .



(**Q**)

Scheme 1.



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References

1) K. Nakamura, Y. Morita, T. Suzuki, T. Sugiyama, and A. Sugimori, Bull. Chem. Soc. Jpn., 52, 488 (1979); K. Nakamura, T. Sugiyama, T. Suzuki, and A. Sugimori, Chem. Lett., 1977, 1203.

2) A. Sugimori, M. Nishijima, and H. Itoh, Bull. Chem. Soc. Jpn., 55, 3055 (1982).

3) J. W. T. Spinks and R. J. Woods, "An Introduction to Radiation Chemistry," 2nd ed, John Wiley, New York (1976), p. 415.

4) The photochemical process in the presence of acetone could proceed via triplet energy transfer from the excited acetone to 4-pyridinecarbonitrile. However, the presence of another triplet sensitizer, benzene, did not promote the ethylation at the 2-position in the presence of sulfuric acid or the substitution of hydroxyalkyl group for CN in the absence of sulfuric acid in the photoreaction of 4-pyridinecarbonitrile in ethanol.

5) In the products from the radiation-induced reaction of 2-pyridinecaronitrile in methanol in the presence of sulfuric acid, formaldehyde was identified as its 2,4-dinitrophenylhydrazone. This fact supports our description of the mechanism of the electron transfer from hydroxyalkyl radicals to the substrate.

$$\cdot CH_2OH + \text{Substrate} \longrightarrow \overset{+}{C}H_2OH + (\text{Substrate})^-$$

$$\overset{+}{C}H_2OH \longrightarrow CH_2{=}O + H^+$$

6) H. Zeldes and R. Livingston, J. Phys. Chem., 76, 3348 (1972).

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