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Pyrolysis of Benzyl 2-Oxazolecarbamates and Benzyl 4-Alkylallophanates

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The pyrolysis of benzyl 2-oxazolecarbamates (I) and benzyl 4-alkylallophanates (II) was investigated. Heating of benzyl 5-phenyl-2-oxazolecarbamate (Ia) at 230°C gave benzyl alcohol and 2-phenyl-6-(5-phenyl-2-oxazolyl)-5*H*-oxazolo[3,2-*a*][1,3,5]triazine-5,7-(6*H*)-dione (IIIa). Compound IIIa was also obtained by heating the azide prepared from 5-phenyl-2-oxazolecarbohydrazide (IVa). In the same way, 2-methyl-6-(5-methyl-2-oxazolyl)-5*H*-oxazolo[3,2-*a*][1,3,5]triazine-5,7(6*H*)-dione (IIIb) and 2-phenyl-6-(5-phenyl-2-thiazolyl)-5*H*-thiazolo[3,2-*a*][1,3,5]triazine-5,7(6*H*)-dione (IIIc) were obtained from the corresponding hydrazides (IVb and IVc). Next, heating of benzyl 4-(2-phenylethyl)-allophanate (IIa) at 230°C gave cyanuric acid (VII), benzyl (2-phenylethyl)carbamate (VIII) and 1,3-bis(2-phenylethyl)-1,3,5-triazine-2,4,6(1*H*,3*H*,5*H*)-trione (IX).

Keywords——benzyl 2-oxazolecarbamate; benzyl 4-alkylallophanate; pyrolysis; 5*H*-oxazolo[3,2-*a*][1,3,5]triazine-5,7(6*H*)-dione; 5*H*-thiazolo[3,2-*a*][1,3,5]triazine-5,7(6*H*)-dione; ethyl 2-thiazolecarboxylate

Previously we reported on the gas chromatography of benzyl 2-oxazolecarbamates (I) and benzyl 4-alkylallophanates (II).[1] It has long been known that alkyl carbamates pyrolyze to isocyanates and alcohols on heating.[2] It has also been reported that 2-thiazolyl isocyanate and 2-pyridyl isocyanate can be cyclodimerized to give 6-(2-thiazolyl)-5*H*-thiazolo[3,2-*a*][1,3,5]-triazine-5,7(6*H*)-dione and 3-(2-pyridyl)-2*H*-pyrido[1,2-*a*][1,3,5]triazine-2,4(3*H*)-dione, respectively.[3] However, these structures were only assigned on the basis of the infrared (IR) and proton nuclear magnetic resonance (PMR) spectra. Nothing is known about the pyrolysis of allophanates. In this paper, we have examined the pyrolysis of I and II in order to elucidate the structures of the pyrolytic products.

Heating of benzyl 5-phenyl-2-oxazolecarbamate (Ia) at 230°C for 20 min under a nitrogen atmosphere afforded benzyl alcohol (66%) and 2-phenyl-6-(5-phenyl-2-oxazolyl)-5*H*-oxazolo-[3,2-*a*][1,3,5]triazine-5,7(6*H*)-dione (IIIa) (73%). Compound IIIa was also obtained in 70% yield by refluxing the benzene solution of the azide prepared from 5-phenyl-2-oxazolecarbohydrazide (IVa). The IR spectrum of IIIa showed carbonyl absorption bands at 1770 and 1710 cm^{-1}. The PMR spectrum exhibited two oxazole ring proton signals at δ 7.91 (1H, s, C_4'–H) and 8.69 (1H, s, C_3–H). The ultraviolet (UV) spectrum showed absorption maxima at 233 (log ε 4.51), 274 (log ε 4.64), 283 (log ε 4.65) and 296 (log ε 4.59) nm, and was similar to that of 2,6-diphenyl-5*H*-oxazolo[3,2-*a*][1,3,5]triazine-5,7(6*H*)-dione (V) as shown in Fig. 1. Compound V was prepared by the reaction of 2-amino-5-phenyloxazole with phenyl isocyanate according to the method of Crank, *et al.*[4] An X-ray crystallographic analysis of IIIa was carried out and its structure was unambiguously established as above; we have reported the details of the X-ray crystallographic analysis.[5]

Similarly, heating of the azide prepared from 5-methyl-2-oxazolecarbohydrazide (IVa) gave 2-methyl-6-(5-methyl-2-oxazolyl)-5*H*-oxazolo[3,2-*a*][1,3,5]triazine-5,7(6*H*)-dione (IIIb) (65%). Further, refluxing of ethoxalylaminoacetophenone and phosphorus pentasulfide in chloroform gave ethyl 5-phenyl-2-thiazolecarboxylate (VI), which was converted to 5-phenyl-2-thiazolecarbohydrazide (IVc). Treatment of IVc in the same manner as IVa gave 2-phenyl-6-(5-phenyl-2-thiazolyl)-5*H*-thiazolo[3,2-*a*][1,3,5]triazine-5,7(6*H*)-dione (IIIc) (73%). The structures of IIIb and IIIc were confirmed on the basis of their physical data as described in the experimental section.

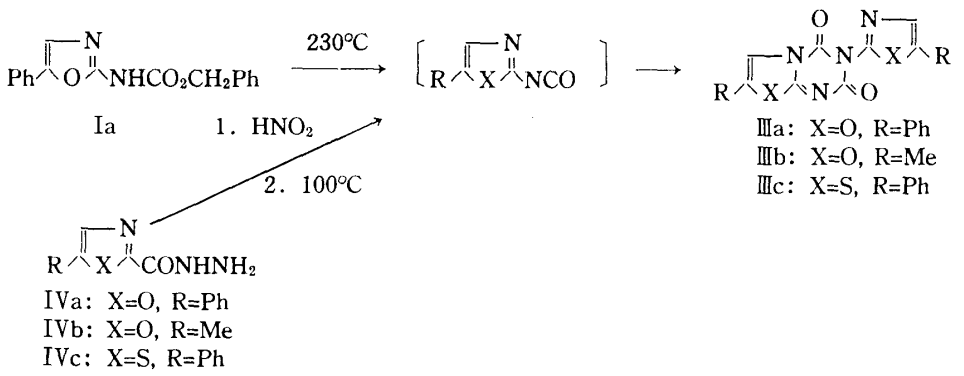

Chart 1

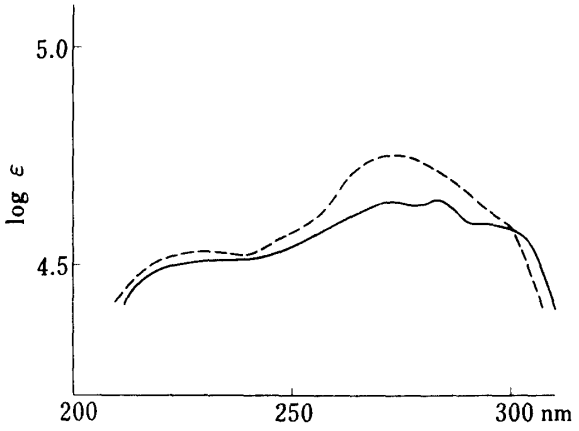

Fig. 1. UV Spectra of IIIa (—) and V (···)

The mass spectra (MS) of oxazolo- and thiazolo[3,2-*a*][1,3,5]triazine derivatives (IIIa, IIIb and IIIc) showed no molecular ion peak but showed a peak corresponding to a half of the total molecular weight. It is known that the MS of some triazine derivatives contain a molecular ion of very low abundance.[6] The fragmentation of III may be presumed to arise rapidly by the common "retro-Diels–Alder" type of cleavage[7] as shown in the previous paper.[5]

Next, heating of benzyl 4-(2-phenylethyl)allophanate (IIa) at 230°C for 30 min under a nitrogen atmosphere afforded cyanuric acid (VII) (25%), benzyl (2-phenylethyl)carbamate (VIII) (36%) and 1,3-bis-(2-phenylethyl)-1,3,5-triazine-2,4,6-(1*H*,3*H*,5*H*)-trione (IX) (26%). The IR spectrum of VIII showed an imine absorption band at 3450 cm^{-1} and a carbonyl absorption band at 1700 cm^{-1}. The PMR spectrum exhibited an ethylene proton signal at δ 2.76 (2H, t, $CH_2\underline{CH_2}Ph$) and 3.42 (2H, q, $C\underline{H_2}CH_2Ph$), and a methylene proton signal at δ 5.06 (2H, s, $OC\underline{H_2}Ph$). Compound VIII was also identical with an authentic sample prepared by

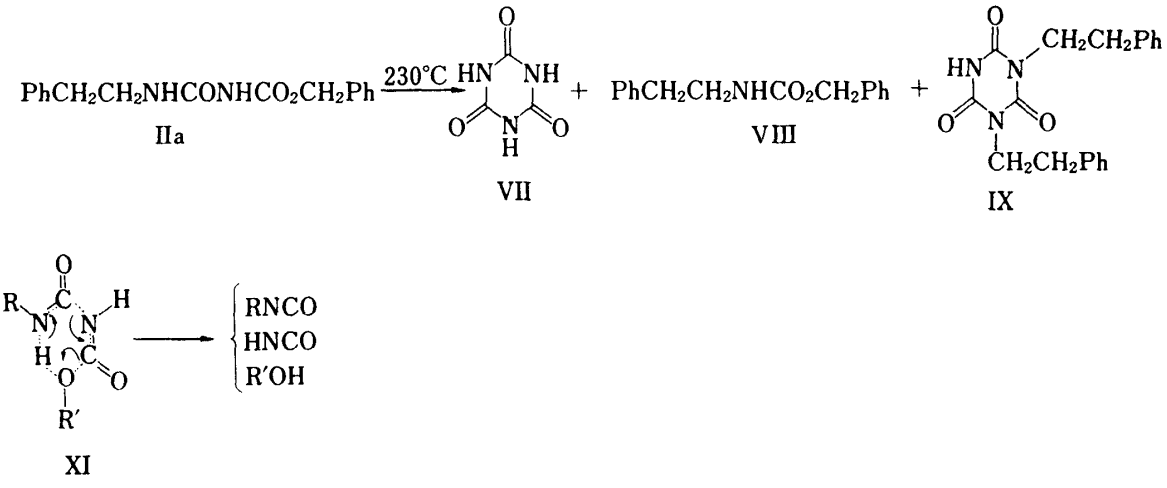

Chart 2

the reaction of 2-phenylethyl isocyanate (X) with benzyl alcohol. The IR spectrum of IX showed an imine absorption band at 3240 cm^{-1} and carbonyl absorption bands at 1725 and 1680 cm^{-1}. The PMR spectrum exhibited two ethylene proton signals at δ 2.78 (4H, t, $2\times CH_2\underline{CH_2}Ph$) and 3.87 (4H, t, $2\times\underline{CH_2}CH_2Ph$), and an imine proton signal at δ 11.7 (1H, s). Compound IX was also identical with the sample prepared by the reaction of X with VII. Benzyl carbamate could not be pyrolyzed at 230°C.

The cyclic transition state was proposed for the pyrolysis of alkyl carbamate.[8] The pyrolytic process of IIa appears to involve two molecular eliminations proceeding through a six-centred transition state of the type shown in XI.

Experimental

All melting points are uncorrected. IR and UV spectra were taken with JASCO IRA-1 and Hitachi EPS-032 spectrophotometers. PMR spectra were taken with a Hitachi Perkin Elmer R-40 spectrometer using tetramethylsilane as an internal standard. MS were taken with a Hitachi RMU-7L mass spectrometer.

Pyrolysis of Benzyl 5-Phenyl-2-oxazolecarbamate (Ia)——Compound Ia (0.5 g) was heated at 230°C for 20 min under a nitrogen atmosphere in a sealed tube. The reaction mixture was distilled under reduced pressure to give benzyl alcohol (0.12 g, 66%). The residue was recrystallized from acetonitrile to give 2-phenyl-6-(5-phenyl-2-oxazolyl)-5*H*-oxazolo[3,2-*a*][1,3,5]triazine-5,7(6*H*)-dione (IIIa) (0.23 g, 73%) as pale yellow plates, mp 235—237°C. IR ν_{max}^{KBr} cm^{-1}: 1770, 1710 (C=O). UV λ_{max}^{THF} nm (log ε): 233 (4.51), 274 (4.64), 283 (4.65), 296 (4.59). PMR (DMSO-d_6) δ: 7.4—7.95 (10H, m, Ar–H), 7.91 (1H, s, $C_{4'}$–H), 8.69 (1H, s, C_3–H). MS *m/z*: 186 (1/2 M^+). *Anal.* Calcd for $C_{20}H_{12}N_4O_4$: C, 64.51; H, 3.25; N, 15.05. Found: C, 64.37; H, 3.08; N, 14.89.

2-Phenyl-6-(5-phenyl-2-oxazolyl)-5*H*-oxazolo[3,2-*a*][1,3,5]triazine-5,7(6*H*)-dione (IIIa)——A solution of $NaNO_2$ (0.38 g) in water (3 ml) was added dropwise to a stirred mixture of 5-phenyl-2-oxazolecarbohydrazide (IVa) (1 g), AcOH (5 ml), conc. HCl (0.6 ml), $CHCl_3$ (10 ml) and benzene (10 ml) at 0—5°C. The stirring was continued for 30 min. The reaction mixture was diluted with water, extracted with benzene, and dried. The solution was concentrated to *ca.* 10 ml, and then refluxed for 1 h. The resulting precipitate was collected by filtration, and recrystallized to give IIIa (0.6 g, 70%), which was identical with the sample obtained above.

2,6-Diphenyl-5*H*-oxazolo[3,2-*a*][1,3,5]triazine-5,7(6*H*)-dione (V)——A mixture of 2-amino-5-phenyloxazole (0.9 g), phenyl isocyanate (2.2 g) and pyridine (3.5 ml) was refluxed for 2 h. The solution was concentrated to dryness *in vacuo*, and the residue was recrystallized from acetonitrile to give V (1.2 g, 70%) as colorless leaflets, mp 280—282°C. IR ν_{max}^{KBr} cm^{-1}: 1750, 1710 (C=O). UV λ_{max}^{THF} nm (log ε): 231 (4.53), 274 (4.75), 281 (4.73), 294 (4.63). PMR (DMSO-d_6) δ: 7.2—8.0 (10H, m, Ar–H), 8.66 (1H, s, C_3–H). *Anal.* Calcd for $C_{17}H_{11}N_3O_3$: C, 66.88; H, 3.63; N, 13.77. Found: C, 66.79; H, 3.50; N, 13.81.

2-Methyl-6-(5-methyl-2-oxazolyl)-5*H*-oxazolo[3,2-*a*][1,3,5]triazine-5,7(6*H*)-dione (IIIb)——5-Methyl-2-oxazolecarbohydrazide (IVb) (1 g) was treated as described for IIIa to give IIIb (0.57 g, 65%) as colorless leaflets, mp 216—218°C, after recrystallization from EtOAc. IR ν_{max}^{KBr} cm^{-1}: 1775, 1710 (C=O). PMR (DMSO-d_6) δ: 2.27 (3H, d, J=1 Hz, $C_{5'}$–CH_3), 2.34 (3H, d, J=1 Hz, C_2–CH_3), 7.04 (1H, q, J=1 Hz, $C_{4'}$–H), 7.65 (1H, q, J=1 Hz, C_3–H). MS *m/z*: 124 (1/2 M^+). *Anal.* Calcd for $C_{10}H_8N_4O_4$: C, 48.39; H, 3.25; N, 22.58. Found: C, 48.51; H, 3.08; N, 22.77.

Ethyl 5-Phenyl-2-thiazolecarboxylate (VI)——A mixture of ethoxalylaminoacetophenone (7 g) and P_2S_5 (13 g) in dry $CHCl_3$ (42 ml) was refluxed for 20 h. The solution was washed with water, and dried. After removal of the solvent by evaporation, the residue was recrystallized from hexane to give VI (6 g, 86.5%) as pale yellow needles, mp 62—63°C. IR $\nu_{max}^{CHCl_3}$ cm^{-1}: 1720 (C=O), 1705 (C=N). PMR ($CDCl_3$) δ: 1.37 (3H, t, J=8 Hz, $CH_2\underline{CH_3}$), 4.42 (2H, q, J=8 Hz, $\underline{CH_2}CH_3$), 7.4—7.9 (5H, m, Ar–H), 8.52 (1H, s, C_4–H). *Anal.* Calcd for $C_{12}H_{11}NO_2S$: C, 61.77; H, 4.75; N, 6.00. Found: C, 61.47; H, 4.52; N, 5.78.

5-Phenyl-2-thiazolecarbohydrazide (IVc)——A solution of VI (4 g) and $NH_2NH_2\cdot H_2O$ (1.3 g) in abs. EtOH (18 ml) was refluxed for 1 h. The solution was concentrated *in vacuo*, and the residue was recrystallized from EtOH to give IVc (3.45 g, 92%) as pale yellow leaflets, mp 166—168°C. IR ν_{max}^{KBr} cm^{-1}: 3260, 3220, 3180 (NH), 1665 (C=O). PMR (DMSO-d_6) δ: 4.66 (2H, br, $NHN\underline{H_2}$), 7.4—7.85 (5H, m, Ar–H), 8.39 (1H, s, C_4–H), 10.21 (1H, s, $N\underline{H}NH_2$). *Anal.* Calcd for $C_{10}H_9N_3OS$: C, 54.55; H, 4.05; N, 19.17. Found: C, 54.55; H, 4.05; N, 19.21.

2-Phenyl-6-(5-phenyl-2-thiazolyl)-5*H*-thiazolo[3,2-*a*][1,3,5]triazine-5,7(6*H*)-dione(III)——Compound IVc (1 g) was treated as described for IIIa to give IIIc (0.6 g, 73%) as pale yellow needles, mp above 300°C, after recrystallization from $CHCl_3$. IR ν_{max}^{KBr} cm^{-1}: 1760, 1740 (C=O). PMR (DMSO-d_6) δ: 7.4—7.85 (10H, m, Ar–H), 8.23 (1H, s, $C_{4'}$–H), 8.39 (1H, s, C_3–H). MS *m/z*: 202 (1/2 M^+). *Anal.* Calcd for $C_{20}H_{12}N_4O_2S_2$: C, 59.39; H, 2.99; N, 13.85. Found: C, 59.50; H, 2.91; N, 14.13.

Pyrolysis of Benzyl 4-(2-Phenylethyl)allophanate (IIa)——Compound IIa (0.4 g) was heated at 230°C for 30 min under a nitrogen atmosphere in a sealed tube. The reaction mixture was treated with $CHCl_3$.

The $CHCl_3$-insoluble material gave cyanuric acid (VII) (0.04 g, 25%). IR ν_{max}^{KBr} cm^{-1}: 3200 (NH), 1690 (C=O). The $CHCl_3$-soluble material was subjected to silica gel column chromatography. The first $CHCl_3$ eluate gave benzyl (2-phenylethyl)carbamate (VIII) (0.12 g, 36%) as colorless needles, mp 56—58°C, after recrystallization from $CHCl_3$–hexane. IR $\nu_{max}^{CHCl_3}$ cm^{-1}: 3450 (NH), 1700 (C=O). PMR ($CDCl_3$) δ: 2.76 (2H, t, $CH_2C\underline{H}_2$-Ph), 3.42 (2H, q, $C\underline{H}_2CH_2Ph$), 5.06 (2H, s, $OC\underline{H}_2Ph$), 7.30 (5H, s, Ar–H), 7.2—7.35 (6H, m, Ar–H and NH). *Anal.* Calcd for $C_{16}H_{17}NO_2$: C, 75.27; H, 6.71; N, 5.49. Found: C, 75.20; H, 6.46; N, 5.70.

Further elution with $CHCl_3$–AcOEt (5: 1) gave 1,3-bis(2-phenylethyl)-1,3,5-triazine-2,4,6(1*H*,3*H*,5*H*)-trione (IX) (0.06 g, 26%) as colorless leaflets, mp 216—218°C, after recrystallization from $CHCl_3$–hexane. IR ν_{max}^{KBr} cm^{-1}: 3240 (NH), 1725, 1680 (C=O). PMR (DMSO-d_6) δ: 2.78 (4H, t, $2\times CH_2C\underline{H}_2Ph$), 3.87 (4H, t, $2\times C\underline{H}_2CH_2Ph$), 7.05—7.4 (10H, m, Ar–H), 11.7 (1H, s, NH). MS *m/z*: 337 (M^+). *Anal.* Calcd for $C_{19}H_{19}N_3O_3$: C, 67.64; H, 5.68; N, 12.46. Found: C, 67.45; H, 5.71; N, 12.52.

Benzyl (2-Phenylethyl)carbamate (VIII)——A solution of 2-phenylethyl isocyanate (X) (0.18 g) and benzyl alcohol (0.2 g) in dry benzene (3 ml) was refluxed for 1 h. The solvent was evaporated off *in vacuo*, and the residue was recrystallized from $CHCl_3$–hexane to give VIII (0.18 g, 57%), which was identical with the sample obtained above.

1,3-Bis(2-phenylethyl)-1,3,5-triazine-2,4,6-(1*H*,3*H*,5*H*)-trione (IX)——A mixture of X (0.32 g) and VII (0.32 g) was heated at 230°C for 10 h in a sealed tube. The reaction mixture was extracted with hot AcOEt. After removal of AcOEt by evaporation, the residue was recrystallized from $CHCl_3$–hexane to give IX (0.29 g, 39%), which was identical with the sample obtained above.

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