In the case of **2a–c**, mixtures of two geometrical isomers were used for cyclization. In view of the almost quantitative yield of **5c** from **2c** (ratio of two geometrical isomers, 3:1), it is clear that cis–trans equilibria between two isomers of isocyanates **2** are established in this reaction.

Experimental Section

Melting points were determined on a Yanagimoto micro melting point apparatus and are corrected. Boiling points are uncorrected. Nmr spectra were obtained using a JNM-G-60 spectrometer (Japan Electronic Optics Laboratory Co.) with tetramethylsilane as an internal reference. Ir spectra were recorded with a Japan Electronic IR-E spectrophotometer or with a Hitachi 225 spectrophotometer equipped with gratings. Mass spectra were recorded with a Hitachi RMU-6E mass spectrometer.

Materials.—Enaminonitriles **1** were prepared according to the known methods.[3,11,14]

Synthesis of Unsaturated Isocyanates 2.—A typical procedure is as follows. In a 100-ml round-bottomed four-necked flask, equipped with a stirrer, a condenser, a dropping funnel, and a gas inlet tube, was placed 30 ml of ethyl acetate and it was saturated with phosgene under reflux. To this solution was added 7.5 g (0.05 mol) of enaminonitrile **1c** in 30 ml of ethyl acetate in 25 min; then the reaction mixture was heated under reflux with stirring for an additional 30 min. The introduction of phosgene was continued throughout these procedures. After phosgene was purged with dry N_2, the solvent was removed under reduced pressure to yield a viscous reddish liquid, which was distilled under reduced pressure to give 6.7 g (72%) of **2c** (colorless liquid).

Reaction of Isocyanate 2 with HCl at 100°.—A typical procedure is as follows. In a 35-ml glass tube were placed 1.1 g (6 mmol) of **2c** and 5 ml of dioxane; then to the mixture 1.45 g (40 mmol) of anhydrous HCl was allowed to be absorbed under cooling. The glass tube was sealed and heated at 100° for 24 hr. After removal of HCl, the precipitates formed were filtered, washed with a small portion of dioxane, and dried *in vacuo* to yield 1.0 g of uracil **5c**. From the filtrate 0.15 g of **5c** was obtained. The total yield was 95%.

Reaction of 2c with HCl at 60°.—In a 35-ml glass tube, a mixture of 0.63 g (3.4 mmol) of **2c**, 1.3 g (36 mmol) of HCl, and 5 ml of dioxane was heated at 60° for 6 hr. After HCl was purged, the precipitates formed were filtered, washed with dioxane, and dried at 80° *in vacuo* to yield a white powder of 6-chloro-5-methyl-4-phenyl-2(3*H*)-pyrimidinone (**4c**) (0.56 g, 74%). The crude product was recrystallized from anhydrous CH_3CN to give colorless needles: mp 190–195°; ir (Nujol) 1665 cm^{-1} (C=O); nmr (CF_3COOH) δ 2.53 (s, 3 H) and 7.82 (s, 5 H); mass spectrum (70 eV) *m/e* (rel intensity) 220 (45, M^+) and 219 (100).

Anal. Calcd for $C_{11}H_9N_2OCl$: C, 59.87; H, 4.11; N, 12.70. Found: C, 59.70; H, 4.05; N, 12.80.

The dioxane was evaporated from the filtrate and the residue was washed with a small portion of dioxane and dried *in vacuo* to yield 0.076 g (10%) of **5c**.

Reaction of Pyrimidinone 4c with HCl in Dioxane.—In a 35-ml glass tube a mixture of 0.119 g of **4c**, 0.8 g of HCl, and 2 ml of dioxane was heated at 100° for 20 hr. The reaction mixture was evaporated to dryness and the resulting residue was washed with ether and dried *in vacuo* to give 0.096 g (88%) of **5c**.

Reaction of Dioxane with HCl at 100°.—In a 50-ml glass tube a mixture of 9.0 g of dioxane and 3.2 g of HCl was heated at 100° for 24 hr. The dioxane was removed under reduced pressure to yield 0.6 g of a mixture of **6** (major) and **7** (minor) (glpc analysis).

Registry No.—*cis*-**2a**, 35042-37-6; *trans*-**2a**, 35042-38-7; *cis*-**2b**, 35042-39-8; *trans*-**2b**, 35042-40-1; *cis*-**2c**, 35042-41-2; *trans*-**2c**, 35042-42-3; **2d**, 30542-43-4 **4c**, 35042-44-5; **5a**, 32796-82-0; **5b**, 16372-00-2; **5c**, 35042-47-8; **5d**, 35042-48-9.

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A *p*-Fluoro Labeling Study of Partial Scrambling before Fragmentation in Some Five-Membered Heterocycles Containing Nitrogen

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Illustrative examples of *p*-fluoro labeled triphenyloxazole, -imidazole, -thiazole, and isoxazole were studied in the mass spectrometer to determine scrambling patterns in major fragmentations. No trends were observed which would have been analogous to the photochemical analogy in the scrambling patterns of furans and thiophenes.

Previously the *p*-fluoro substituent has been used as a label[1] to study scrambling in the decomposition of several five-[2,3] and six-membered[4] heterocycles in the mass spectrometer. Partial to complete scrambling before fragmentation was observed in the cases of tetraphenylfuran and tetraphenylthiophene,[3] in analogy to the behavior of furan and thiophene themselves in the mass spectrometer[5] and to the photochemical behavior of substituted thiophenes[6] and furans.[7] In distinction to the mass spectral behavior of pyridine,[8] however, the completely phenylated derivatives of pyridine, pyrazine, and 1,2,4-triazine were found not to scramble appreciably before decomposition.[4] We therefore thought it of interest to examine the extent of scrambling before fragmentation for several fully phenylated five-membered heterocycles containing nitrogen. This report is concerned with the scrambling in various fragment ions of 4,5-diphenyl-2-*p*-fluorophenyloxazole (I), 4,5-diphenyl-2-*p*-fluorophenylimidazole (II), 2,5-bis(*p*-fluorophenyl)-4-phenylthiazole (III), and 3,5-diphenyl-4-*p*-fluorophenylisoxazole (IV). Fragmentation of other substituted triphenyl isox-

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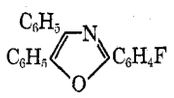

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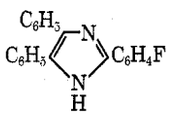

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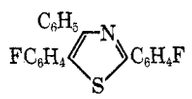
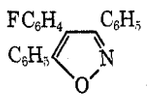


III



IV

azoles has been reported, and we specifically note the lack of important scrambling processes preceding several cleavages studied therein.[9]

Data for distribution of the label between fragment ions of similar composition for compounds I–IV are given in Table I.

TABLE I

RATIOS OF COMPARABLE FRAGMENT ION INTENSITIES IN THE MASS SPECTRA OF I–IV

	I	II	III	IV
$\frac{M - FC_6H_4CN}{M - C_6H_5CN}$	1.0	6.4[a]	1200	0.08
$\frac{C_{13}H_9F}{C_{13}H_{10}}$	2.5	0.08	30	0.9
$\frac{C_{13}H_8F}{C_{13}H_9}$	0.7	0.05	14	2.3
$\frac{FC_6H_4CN}{C_6H_5CN}$	20	2.0	18[b]	0.25
$\frac{FC_6H_4CO}{C_6H_5CO}$	0.18		0.7[c]	0.002
$\frac{FC_6H_4}{C_6H_5}$	0.22	0.4	1.4	0.07

[a] Ratio for ions $[M - FC_6H_4CNH]/[M - C_6H_5CNH]$. [b] Ratio for ions FC_6H_4CHNH/C_6H_5CHNH. The ratio for FC_6H_4CNH/C_6H_5CNH is 1.3. [c] Ratio for ions FC_6H_4CS/C_6H_5CS.

The loss of the elements of benzonitrile from the molecule ion (or, in the case of II, benzonitrile + H) is specific in the case of the thiazole III and fairly specific for the isoxazole IV, but is not specific (this need not imply scrambling) in the oxazole I and the imidazole II. In I, it may be argued that the aryl group on either side of N is lost equally easily (though other more complex arguments might be invented); in II, the substituent at C-2 is lost more frequently than the others; in III, a substituent at C-2 (or less likely C-5) is lost to the exclusion of that at C-4; and, in IV, the loss of the substituent at C-3 (or less likely C-5) is favored over the loss of the C-4 substituent. Sulfur, in this series of compounds, does not accelerate the rate of internal scrambling relative to the first-row elements. This is in decided contrast to the behavior of five-membered heterocycles containing only oxygen or sulfur, where the dominant effect of sulfur seems to be promotion of scrambling. Here the dominant effect of sulfur is to promote a specific cleavage.

The formation of the ions $C_{13}H_{10}\cdot^+$, $C_{13}H_9^+$, and their fluorinated analogs is reasonable against the background of ready formation of these ions in the decomposition of many classes of compounds containing at least two phenyl groups.[10] Since there are two ways of choosing one substituted ring and one unsubstituted ring, but only one way of choosing two unsubstituted rings in I, II, and IV, complete scrambling before production of this ion would produce a ratio of two monofluorinated to one unflorinated C_{13} ion. Hence, total scrambling is very nearly approached in the $C_{13}H_{10}$ ion of the oxazole I and the $C_{13}H_9$ ion (but not the $C_{13}H_{10}$ ion!) of the isoxazole IV. In all other cases, ions seem to be formed with only a small amount of scrambling; the data for III are reasonable in the minimal amount of unfluorinated ions formed, since it is not possible to choose two unsubstituted rings in III. The formation of any $C_{13}H_{10}$ or $C_{13}H_9$ must be complex process, but very little is formed of these ions. Incidentally, there is virtually no $C_{13}H_8F_2\cdot^+$ or $C_{13}H_7F_2^+$ produced by III, again suggesting that sulfur promotes cleavage, not scrambling, in the production of fragment ions in this series.

The data for the production of FC_6H_4CN/C_6H_5CN should be compared with the data for the expulsion of these fragments from the molecular ion. In every case, the scrambling is significantly different from that for loss of benzonitrile; consequently, the mechanisms for these two processes cannot be closely related. This is unexpected, because naive assumptions would have led to the only distinction as the placement of the charge. Again, the sulfur atom in the thiazole has not produced significantly greater scrambling than the oxygen atom in the oxazole.

Benzoyl ion formation in I from C-2 is discriminated against, relative to C-5, by a factor of 4 or 5 (or, relative to C-4 and C-5, by a factor of less than 3 if there is total scrambling); in the isoxazole, as noted before in cases with other substituents,[9] the process is specific. The thiobenzoyl ion III involves substantial contribution from C-4, and serves as one of the few ions produced after bond formation across the ring initiated by sulfur but not so much by oxygen.

Finally, the small fragment corresponding to the phenyl group is formed with less than statistical origin in each case, particularly IV.[9] Deviations from the statistical values of 2:1 are about 50% in the oxazole I, 25% in the imidazole II, and 35% in the thiazole.

There are several fragmentations peculiar to certain species, so that relative behavior across the series of compounds cannot be compared as in the above cases. In the imidazole, the ratio of loss of labeled to unlabeled (benzonitrile + H_2) is 4.7. This number suggests that the mechanism for loss of these components is closely related to that for the loss of (benzonitrile + H), but not to the formation of $C_6H_5CHNH\cdot^+$ or $C_6H_5CNH^+$, where the scrambling values are different. Peaks of mass corresponding to difluorodiphenylacetylene and fluorodiphenylacetylene appear in the spectrum of the thiazole III in the ratio of 0.07, indicating that only a small amount of bond formation across the ring occurs before formation of these virtual hydrocarbon ions.

Low-Voltage Studies.—Most of the processes noted are high-energy processes and do not lend themselves to study at reduced voltages. A study of spectra at

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voltages between 40 and 12 V ionizing energy led to the following observations.

In the oxazole I, the $[C_{13}H_9F\cdot^+]/[C_{13}H_{10}\cdot^+]$ ratio increases from 2.5 at 70 V to 7 at 20 V; in the imidazole and thiazole, the $[C_{13}H_8F^+]/[C_{13}H_9^+]$ ratio remains constant at low voltage. The routes of formation of these ions are therefore convergent, since the oxazole begins to approach specificity and the others remain nearly specific.

In the oxazole, the $[FC_6H_4^+]/[C_6H_5^+]$ ratio exceeds 30 at 40 V; in the imidazole, it drops somewhat to 0.15 at 40 V. A specific process is therefore indicated involving the C-2 substituent in the oxazole, but the analogy does not hold in the imidazole.

The $[M - FC_6H_4CNH^+]/[M - C_6H_5CNH^+]$ ratio is 0.14 at 40 V in the imidazole, a striking reversal of the behavior at 70 V. This observation suggests that at least two specific processes may be involved in the formation of the ion, one dominant just above threshold and the other becoming more important at higher ionizing voltage. The most closely analogous process which could be studied, loss of benzonitrile from the thiazole, does not undergo such a reversal, the ratio dropping from 1200 at 70 V to 300 at 17.5 V ionizing energy.

Finally, in the thiazole, the difluorodiphenylacetylene/fluorodiphenylacetylene ratio drops by an order of magnitude at 20 eV.

Conclusions

The scrambling processes in these compounds do not follow the trend of greater scrambling as one moves down the periodic table in choosing a heteroatom, as might have been expected from the photochemical analogy in scrambling of furans and thiophenes in the mass spectrometer.[3,5] The introduction of a heteroatom seems to have the principal effect of making certain fragmentation routes more favorable. Usually the competition of this decomposition process with scrambling mechanisms is favorable to fragmentation.

Experimental Section

Mass Spectra.—The spectra were recorded on a Hitachi RMU-6E mass spectrometer, with sample introduction by direct-probe insertion at the minimum temperature required to produce a useable spectrum (160–275°). For conventional spectra the ionizing voltage was 75 V and the repeller voltage was 2 V, the temperature of the source being maintained at 190°. The ionizing current was 80 μA and the trap current 50 μA. Low-voltage spectra were collected with ionizing voltages of 40, 30, 25, 20, 17.5, and 15 V, with tied repellers set at 0 V.

Synthesis. 4,5-Diphenyl-2-*p*-fluorophenyloxazole (I).—This was prepared by the general method of Murray and Japp[11] and was recrystallized from EtOH, mp 118°.

Anal. Calcd: C, 80.0; H, 4.44. Found: C, 79.99; H, 4.55.

4,5-Diphenyl-2-*p*-fluorophenylimidazole (II).—A method adapted from that of Radziszewski[12] was used; benzil (0.05 mol), *p*-fluorobenzaldehyde (0.04 mol), and NH_3 (enough to saturate) were dissolved in the minimum of EtOH at 40° and left standing for 48 hr, mp 275° from EtOH.

Anal. Calcd: C, 80.25; H, 4.77. Found: C, 80.38; H, 4.81.

2,5-Bis(*p*-fluorophenyl)-4-phenylthiazole (III).—This was prepared by a procedure described by Hubacher,[13] mp 115.5° from ether, then EtOH.

Anal. Calcd: C, 72.20; H, 3.72. Found: C, 72.08; H, 3.66.

3,5-Diphenyl-4-*p*-fluorophenylisoxazole (IV).—The method of preparation was analogous to those described by Kohler and Barrett[14] and Meisenheimer and Weibezahn,[15] mp 231–232° from MeOH.

Anal. Calcd: C, 80.0; H, 4.44. Found: C, 80.27; H, 4.51.

Registry No.—I, 35040-28-9; II, 2284-96-0; III, 35040-30-3; IV, 35040-31-4.

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