tate appeared within 15 min after addition of the ethyl chloroformate. Filtration of the reaction mixture yielded 1.74 g of material characterized as 6a,8-diacetate hydrochloride **4**·HCl, mp 269.5–270° dec, by mixture melting point and comparison with the infrared spectrum of an authentic sample produced by adding diethyl ether saturated with hydrogen chloride gas to an ether solution of 6a,8-diacetate **4** and recrystallizing from ethyl alcohol–ethyl acetate. The infrared spectrum showed hydroxyl at 3340 and 3130 cm^{-1} and carbonyl at 1745 cm^{-1}.

Anal. Calcd for $C_{17}H_{28}O_6NCl$: C, 54.04; H, 7.47; N, 3.71; Cl, 9.47. Found: C, 54.14; H, 7.40; N, 3.65; Cl, 9.81.

The tetrahydrofuran filtrate was evaporated under reduced pressure and the residue suspended in ethyl acetate and filtered yielding 0.656 g, mp 202° dec.[15] The infrared spectrum showed hydroxyl at 3290 cm^{-1} and carbonyl at 1738 cm^{-1} and also indicated the product was a mixture containing about 50% 6a,8-diacetate hydrochloride **4**·HCl. Further characterization was done on the free amine.

1,3,4,6,6a,7,8,9,10,10a,11,11a-Dodecahydro-2H-benzo[*b*]quinolizine-6a,8,9,10a-tetrol 6a,8-Diacetate 10a-Ethyl Carbonate (6).—The mixture of hydrochloride salts of **4** and **6** (0.051 gm) was dissolved in 10 ml of water in a separatory funnel and ice added. Chloroform (10 ml) followed by 7 *N* ammonium hydroxide to pH 8–9 (pHydrion paper) was then added and the mixture strongly agitated. The chloroform phase was removed and the aqueous phase extracted twice more with chloroform (10 ml portions). The chloroform extracts were dried over anhydrous magnesium sulfate and then removed under reduced pressure. The viscous residue solidified upon treatment with Skellysolve B. The presence of 6a,8-diacetate **4** starting material was shown by thin layer chromatography. The infrared spectrum showed hydroxyl at 3490 cm^{-1} and carbonyl at 1760, 1735, and 1715 cm^{-1}. The nmr spectrum showed significant signals at δ 4.98 (W_H = 8 cps, C-8 equatorial carbinol proton) and δ 3.91 (W_H = 8 cps, C-9 equatorial carbinol proton). The latter partially blocked the quartet at δ 4.10 (J = 7 cps), but the triplet at δ 1.28 (J = 7cps) confirmed the presence of ethoxy.

Characterization of 6. A. Formation of 1,3,4,6,6a,7,8,9,10,10a,11,11a-Dodecahydro-2H-benzo[*b*]quinolizine-6a,8,9,10a-tetrol 6a,8,9-Triacetate 10a-Ethyl Carbonate (8).—Using reported procedures,[3] the mixture of compounds **4** and **6** was acetylated yielding a mixture of 6a,8,9-triacetate[3] and **8**. Several recrystallizations from Skellysolve B yielded an almost one spot material whose infrared spectrum was identical in all respects with that of the known material.[3]

B. Formation of 1,3,4,6,6a,7,8,9,10,10a,11,11a-Dodecahydro-2H-benzo[*b*]quinolizine-6a,8,9,10a-tetrol 6a,8-Diacetate 9,10a-Carbonate (7).—The mixture of compounds **4**·HCl and **6**·HCl (0.38 g) was dissolved in 10 ml of water and 7 *N* ammonium hydroxide added until pH 8–9 (pHydrion paper). The mixture became cloudy but cleared up again with the addition of more water. The solution was allowed to stand at room temperature for several minutes and then extracted with chloroform (three 10-ml portions). The chloroform extracts were dried over anhydrous magnesium sulfate and then removed under reduced pressure. The residue was chromatographed on silica gel (J. T. Baker). The desired cyclic carbonate diacetate was eluted with chloroform. Crystallization from Skellysolve B yielded 0.016 gm, mp 170°, of material whose infrared spectrum was identical with that of the known compound.[3] Further elution of the column with $CHCl_3$–CH_3OH (9:1) yielded the 6a,8-diacetate **4**.

Registry No.—**4**, 25683-77-6; **4**·HCl, 25683-78-7; **5**, 25683-79-8; **5**·HCl, 25683-80-1.

(15) The total yields do not add up to 100% of starting material. The proportions of each product reported here are similar in both large and small scale experiments. Addition of an ethereal solution of hydrogen chloride which should convert all basic nitrogenous material to hydrochloride salts had no effect on the yields. Since the starting material is a tertiary amine, there is probably decomposition of the type reported for tertiary amines in the presence of chloroformates. *Cf.* J. D. Hobson and J. G. McClusky, *J. Chem. Soc. C*, 2015 (1967).

Vinylpyrazoles

S. TROFIMENKO

Contribution No. 1684 from the Central Research Department, Experimental Station, E. I. du Pont de Nemours and Company, Wilmington, Delaware 19898

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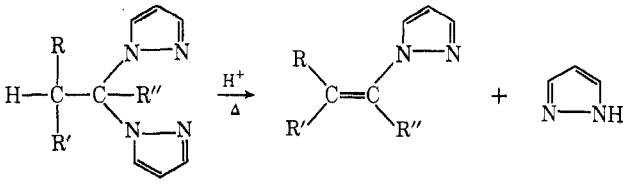
1-Vinylpyrazole and its vinyl-substituted analogs have been prepared by acid-catalyzed cracking of geminal bis(1-pyrazolyl)alkanes. 1-Vinylpyrazole polymerizes under free-radical initiation to a high polymer; the extent of polymerization diminishes with increasing substitution on the vinyl group. The various 1-vinylpyrazoles do not behave as enamines. Shielding effects of a 1-pyrazolyl substiuent on the gem, cis, and trans vinyl protons have been determined.

In the area of pyrazole chemistry there are few examples of 1-pyrazolyl olefins. Apart from the addition products of pyrazole to acetylenedicarboxylic ester,[1,2] and the 1-vinylpyrazoles obtained by the high-pressure reaction of acetylene with 3,5-dimethylpyrazole and 3-methyl-5-phenylpyrazole,[3] some 1-propenylpyrazoles have been synthesized by the pyrolysis of certain α,β-unsaturated azines.[4] A general synthesis of 1-pyrazolyl olefins has been lacking.[4a]

During our work with geminal poly(1-pyrazolyl)alkanes[5] which are available from the reaction of pyrazole with acetals or ketals, a convenient way was found for synthesizing the parent 1-vinylpyrazole and its analogs containing various alkyl substituents on the vinyl group. The method consists of heating geminal bis(1-pyrazolyl)alkanes which contain β hydrogens in the presence of a strong acid such as *p*-toluenesulfonic. Around 200° fragmentation to pyrazole and an olefin occurs. The pyrolysis products are removed as formed



by distillation at atmospheric or reduced pressure and they can be separated with ease.

The cyclic and acyclic 1-pyrazolyl olefins prepared by this method (Table I) are water-insoluble liquids possessing an "olefinic" odor. Their structure assignment rests, apart from the mode of formation and full

(1) E. Benary, H. Meyer, and K. Charisius, *Ber.*, **59**, 108 (1926).

(2) R. M. Acheson and P. W. Poulter, *J. Chem. Soc.*, 2138 (1960).

(3) N. O. Jones, British Patent 887,365 (1962); *Chem. Abstr.*, **57**, 1077*h* (1962).

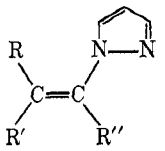
(4) R. L. Stern and J. G. Krause, *J. Org. Chem.*, **33**, 212 (1968).

(4a) NOTE ADDED IN PROOF.—The synthesis of 1-vinylpyrazole from 1-(2-hydroxyethyl)pyrazole has also been reported: I. I. Grandberg and G. J. Sharova, *Khim. Geterotsikl. Soedin.*, **2**, 325 (1968); *Chem. Abstr.*, **69**, 96564*k* (1968).

(5) S. Trofimenko, *J. Amer. Chem. Soc.*, **92**, 5118 (1970).

TABLE I

COMPOUNDS OF STRUCTURE



Compd[a]	R	R	R''	Bp, °C (mm)	Yield, %	$n^{25}D$	Uv, λ_{max} (ϵ)	Nmr $J_{RR'}$, Hz	$J_{R'R''}$, Hz	$J_{RR''}$, Hz	ν_R, τ	$\nu_{R'}$, τ	$\nu_{R''}$, τ
1	H	H	H	139–140 (atm)	39	1.5138[b]	250 (13,150)	0.9	8.7	15.6	4.55	5.28	3.01
2	H	H	CH_3	154–155 (atm)	46	1.5118	249 (11,000)	0	0.6	1.3	4.75	5.43	7.78
3	CH_3	H	H	167–169 (atm)[c]	62[c]	1.5139[c]	249[c] (10,600)	7.3	9.3	1.9	8.03	4.80	3.28
4	H	CH_3	H					6.9	1.5	13.9	4.01	8.25	3.22
5	CH_3	H	C_2H_5	108 (14)[d]	47[d]	1.4990[d]	242[d] (8100)	7.1	1.2	1.4	8.42	4.68	7.53 (CH_2)
6	H	CH_3	C_2H_5					7.2	0.6	0	4.35	8.27	7.35 (CH_2) 9.02 (CH_3)
7	H	H	C_2H_5					0	0	1.2	4.80	5.38	7.35 (CH_2) 8.86 (CH_3)
8	H	CH_3	CH_3	54 (6.0)[e]	84[e]	1.5082[e]	245[e] (8330)	7.2	0	1.2	4.18	8.26	7.85
9	CH_3	H	CH_3					7.2	1.3	1.2	8.33	4.78	7.85
10	CH_3	CH_3	H	75–76 (19)	56	1.5065	243 (10,800)	0	1.4	1.4	8.25	8.20	3.40
11	H	$-(CH_2)_3-$		57 (0.6)	73	1.5462	253 (12,000)	Nmr data[f] 2 d (unres) 2.76; "t" (1.9 and 2.4) 4.10; m 4.24, m 7.92, m 8.26, m 8.74 [2:1:1:2:2:4]					
12	H	$-(CH_2)_4-$		69 (0.6)	78	1.5412	250 (10,200)	2 d (unres) 2.84; "t" (1.8 and 2.4) 4.13; quint (J = 2.2 Hz) 4.62; m 7.5–8.7 [2:1:1:6][f]					

[a] Satisfactory C, H, and N analyses (±0.3%) were obtained for all compounds: Ed. [b] d^{25} = 0.9902 g/ml. [c] A 19:81 mixture of **3** and **4**. [d] A 17:83 mixture of **5** and **6**. [e] An 18:69:13 mixture of **7**, **8**, and **9**. [f] Listed are multiplicity (J) τ [peak ratio].

elemental analysis, on their nmr spectra. These indicated, in each case, the presence of a 1-substituted pyrazole ring and of the appropriate olefinic moiety. While in some instances unambiguous assignment could be made based on the magnitude of coupling constants alone, in others, particularly those involving cis–trans pairs, use had to be made of additive shielding increments.

In 1-vinylpyrazole (**1**) the three vinylic hydrogens appear at τ 3.01, 4.55, and 5.28 and were assigned to the gem, cis, and trans[6] hydrogens respectively on the basis of their coupling constants (J^{cis}_{H-H} = 8.7 and J^{trans}_{H-H} = 15.6 Hz) which were in the expected range for vinylic protons.[7,8] The corresponding values for 1-vinyl-3,5-dimethylpyrazole were found to be 8.8 and 15.3 Hz, respectively.

1-(2-Propenyl)pyrazole (**2**) had the vinylic hydrogens at τ 4.75 and 5.43. Here, geminal coupling was zero, while J_{H-CH_3} values were small (0.6 and 1.3 Hz) and not a distinguishing feature. However, considering the additive shielding parameters of alkyl groups[9,10] namely, −0.45 (gem), +0.22 (cis), and +0.28 ppm (trans), and starting with the chemical shifts of conclusively identified vinylic hydrogens in 1-vinylpyrazole, the cis and trans hydrogens in **2** should be at about τ 4.8 and 5.5, respectively. This correlates well with the observed 4.75 and 5.43 peaks and makes assignment possible.

From precursors capable of giving cis–trans mixtures such mixtures were obtained. For instance, fragmentation of 1,1-bis(1-pyrazolyl)propane produced the cis and trans isomers, **3** and **4**. Although they were not separated by distillation, their mixture could be analyzed by nmr again taking advantage of the cis and trans coupling constants. The major component (81%) was the trans isomer, **4**, as established from it J_{H-H} which was 13.9 Hz, while J^{cis}_{H-H} of the minor component was 9.3 Hz. This compares well with corresponding values in *N*,*N*-diethyl-1-propenylamine which have been reported as 13.7 and 8.6 Hz.[11]

Another example of a single product consisting of a cis–trans mixture was 1-[3-(2-pentenyl)]pyrazole (**5** and **6**) derived from 3,3-bis(1-pyrazolyl)pentane. Here, the coupling constants were of no help in identifying the isomers. On the other hand, by the use of additive shielding increments values of τ 4.3 and 4.9 were predicted for the cis and trans vinyl hydrogens. Accordingly, the vinyl peaks at 4.35 and 4.68 were assigned to the cis (**5**) and trans (**6**) isomers, respectively, which were present in 17:83 ratio. Of interest was the absence of trans H—CH_2 coupling, while $J^{cis}_{H-CH_2}$ was 1.2 Hz. The cis and trans couplings of CH_3 and CH_2 were 0.6 and 1.4 Hz, respectively.

A more complicated product mixture arose from 2,2-bis(1-pyrazolyl)butane, where two modes of eliminating pyrazole are possible. The product mixture consisted of 1[2-(2-butenyl)]pyrazoles and 1-[2-(1-butenyl)]pyrazole (**7**) in 82:18 ratio. These compo-

(6) Gem, cis, and trans will be used in reference to the 1-pyrazolyl substituent unless stated otherwise.

(7) Frank A. Bovey, "Nuclear Magnetic Resonance Spectroscopy," Academic Press, New York, N. Y., 1969, p 358 ff.

(8) "High Resolution Nuclear Magnetic Resonance Spectroscopy," J. W. Einsley, J. Feeney, and L. H. Sutcliffe, Ed., Vol. 2, Pergamon Press, N. Y., 1966, p 1137.

(9) U. E. Matter, C. Pascual, E. Pretsch, A. Pross, W. Simon, and S. Sternhell, *Tetrahedron*, **25**, 691 (1969).

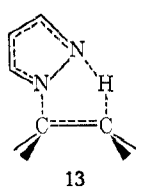
(10) S. W. Tobey, *J. Org. Chem.*, **34**, 1281 (1969).

(11) J. Sauer and H. Prahl, *Tetrahedron Lett.*, 2863 (1966).

nents were not separable by simple fractional distillation, although the lower-boiling cut was enriched in **7** and one of the 1-[2-(2-butenyl)]pyrazole isomers (**9**, *vide infra*). As with **5** and **6**, the cis–trans isomers were identified on the basis of the chemical shift of the vinyl proton: the one at τ 4.18 belonged to **8** while that at 4.78 to **9**. From that assignment the identity of the other peaks was deduced. The **8**:**9** ratio was 84:16, the trans isomer being again the major component. Just as in the case of **5**, the trans H-CH_2 coupling in **7** was zero, but $J^{cis}_{H\text{-}CH_2}$ was 1.2, whereas $J^{cis}_{H\text{-}CH_3}$ and $J^{trans}_{H\text{-}CH_3}$ were about equal (1.2–1.3 Hz).

Compounds **10**, **11**, and **12** presented no structure assignment problems as in each case only one product could be formed containing a vinyl hydrogen of established stereochemistry. The various chemical shifts and coupling constants for the vinyl substituents are listed in Table I. In general, the chemical shifts of all the vinyl protons were close to the positions predicted by the "additive" method, when 1-vinylpyrazole was used as standard. From the twelve examples of 1-vinylpyrazoles reported to this paper we have derived, using the relationship $\delta_{C=C-H}$ (in τ) = 4.75 + Z_{gem} + Z_{cis} + Z_{trans} and the reported additive increments for alkyl groups,[9] the appropriate additive increments for the 1-pyrazolyl substituent. They are −1.77 ± 0.05 for gem, −0.32 ± 0.14 for cis, and +0.37 ± 0.17 Hz[12] for trans and thus they differ not only in the magnitude of the shift but also in the direction for the cis substituent from those reported for NR_2 groups[9] where both cis and trans substituents cause upfield shifts.

The three cis–trans isomer pairs, **2** and **3**, **5**, and **6**, and **8** and **9** all show the trans isomer to be the major (over 80%) component of the mixture. This may be rationalized as follows: the cracking out of pyrazole is unlikely to proceed through a cyclic transition state, **13**, since in the absence of acid the geminal bisalkanes can



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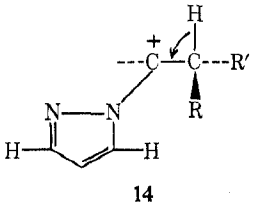

14

be distilled at even higher temperatures without decomposition. Hence, the reaction probably proceeds *via* 2-*N*-protonation of a pyrazolyl group followed by dissociation to yield the carbonium ion **14** of sufficient lifetime to permit some rotation around the C–C bond. The conformation which minimizes nonbonding interactions between pyrazolyl 3,5 hydrogens and the R,R′ substituents will be that which has the bulkier substituent R′ remote from the pyrazolyl group. Such a geometry would lead preferentially, after loss of proton, to the trans isomers (for R′ = alkyl, R = H).

Vinylpyrazole and substituted vinylpyrazoles do not resemble enamines in reactivity. This is in accord with nonavailability of electrons from the 1 nitrogen to stabilize dipolar structures of transition states such as those commonly invoked to account for the reactivity of enamines. Vinylpyrazoles coexist with pyrazole and show no tendency to add it back. Shelf-life of vinylpyrazoles is good and no polymerization in the neat liquid is observed even after 2 years.

Polymerization of these monomers has been effected with azo initiators, although the rate and extent of polymerization depend on the nature of the substituents on the vinyl group. Thus, while neat 1-vinylpyrazole polymerizes almost explosively, 1-(2-propenyl)-pyrazole polymerizes to a lesser extent and the more heavily substituted analogs even less so. In dilute benzene solution 1-vinylpyrazole has been cleanly polymerized to polymers of mol wt 150,000–330,000. Transparent stretchable and orientable films have been cast from 17% methanolic solutions of poly-1-vinylpyrazole.

Experimental Section

The geminal bis(1-pyrazolyl)alkanes[5] and 1-vinyl-3,5-dimethylpyrazole[3] were prepared by published procedures. The nmr spectra were determined routinely on a Varian A-60 spectrometer, using 10% solution of the compound in carbon tetrachloride with internal tetramethylsilane as standard. In some instances, when signals overlapped, their separation (for the determination of *J* values only) was effected by the use of a Varian HA-100 or Varian HR-220 spectrometer, or by employing a neat sample. The chemical shifts changed for some compounds significantly (up to 0.5 ppm) on going from a CCl_4 solution to a neat sample, for others (*e.g.*, 1-vinylpyrazole) not at all.

Synthesis of 1-Vinylpyrazole and of Substituted Analogs.—A general procedure for the preparation of 1-vinylpyrazole and of substituted 1-vinylpyrazoles consists of heating a geminal bis(1-pyrazolyl)alkane to 200–220° in the presence of about 1 g/mol of *p*-toluenesulfonic acid and distilling the two products, pyrazole and 1-pyrazolyl olefin. Pressure may be reduced for distillation of the higher boiling 1-pyrazolyl olefins but it should be adjusted so that the pot temperature remains around 200°. The distillate may contain, in addition, some unreacted geminal dipyrazolylalkane. The three components may be separated by a variety of methods. Pyrazole (bp 185°) plus 1-vinylpyrazole (bp 138°) can be separated by fractional distillation through an efficient column. In some systems much of the pyrazole crystallizes and the olefin may be dissolved in petroleum ether in which pyrazole is sparingly soluble. The petroleum ether extract is then washed with water to remove any pyrazole and the last traces of pyrazole are destroyed by the addition of sodium or calcium hydride to the concentrated organic phase prior to distillation. The olefin is easily separated from the geminal bis(1-pyrazolyl)alkane by fractional distillation. Throughout the purification, the composition of the mixture may be conveniently monitored by nmr.

The procedure is illustrated by a specific example. Other compounds prepared in this fashion are listed in Table I. In the case of vinylpyrazole and propenylpyrazoles some product was lost through polymerization in the pot.

1-Cyclohexenylpyrazole.—A mixture of 195 g (0.9 mol) of 1,1-bis(1-pyrazolyl)cyclohexane and 0.9 g of *p*-toluenesulfonic acid was stirred and heated until pyrazole starting distilling at atmospheric pressure. At this point distillation was continued at reduced pressure, the pressure being adjusted so that the pot temperature remained at 200–210°, until the pot was practically dry. The distillate, a part of which had solidified, was stirred with petroleum ether and the mixture was filtered. There was obtained 40 g (66%) of pyrazole. The filtrate was extracted three times with 500 ml of water (to remove any remaining pyrazole) and was then stripped. The residual oil was distilled *in vacuo*, after some calcium hydride was added, and the heart cut was obtained in 104 g (78%) yield. Its properties are listed in Table I.

Polymerization of 1-Vinylpyrazole.—Exactly 50.0 ml (49.5 g) of pure 1-vinylpyrazole in 200 ml of benzene was stirred at 75–80°. About 4–5 mg of azobisisobutyronitrile was added and stirring was continued for 30 min. When the solution became quite viscous, another 100 ml of benzene and 4 mg of initiator was added and this was repeated 30 min later. The viscous solution was poured into rapidly stirred 2.2 l. of hexane. The resulting

(12) These are root mean square deviations.

fibrous solid was filtered, washed thoroughly with hexane, and dried. It was then cut into small pieces and shredded in a blender under hexane. Filtration and subsequent drying at 100° (1 mm) gave 46.8 g (94.7%) of snow-white polymer: DTA, small endotherms at 80° and 117°, degradation endotherm peaks at 450°; TGA, 5% weight loss at 381°, 94.7% loss at 500°; inherent viscosity (0.1% in $CHCl_3$) 1.62.

Anal. Calcd for $(C_5H_6N_2)_n$: C, 63.8; H, 6.43; N, 29.8. Found: C, 63.5; H, 6.47; N, 29.7; mol wt (osmometric in dioxane), 148,500.

In similar experiments polymers with inherent viscosities of 3.13 and 1.76 and apparent mol wt of 250,000–360,000 were obtained.

Poly(2-propenylpyrazole).—To a solution of 50 ml of 1-(2-propenyl)pyrazole in 100 ml of benzene was added about 4 mg of azobisisobutyronitrile and the solution was stirred at 80° for 30 min. Another 4 mg of initiator was added and this was repeated after another 20 min. After a total of 3 hr at 80°, the thick solution was poured into 2 l. of stirred hexane. A solid which precipitated was filtered, washed with hexane, and dried *in vacuo*. The polymer was obtained in 32-g (67%) yield.

Anal. Calcd for $(C_6H_8N_2)_n$: C, 66.6; H, 7.46; N, 25.9. Found: C, 65.7; H, 7.44; N, 26.2.

Registry No.—**1**, 20173-98-2; **2**, 25834-28-0; **3**, 25834-29-1; **4**, 25834-30-4; **5**, 25834-31-5; **6**, 25834-32-6; **7**, 25834-33-7; **8**, 25834-34-8; **9**, 25834-35-9; **10**, 25834-36-0; **11**, 25834-37-1; **12**, 25834-38-2; 1-vinylpyrazole polymer, 25823-41-0; poly(2-propenylpyrazole), 25823-42-1.

Cleavage of Pyridyl Methyl Ethers and Reactions of 3-Halopyridines with Sodium Methoxide

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2-, 3- and 4-methoxypyridine and also anisole are readily cleaved to their hydroxy arenes and methyl ether in an SN2 reaction by sodium methoxide in methanol. At 164.7° the methoxypyridines react at relative rates 1.0:1.1:2.8, respectively. Using CD_3OD–D_2O as solvent and nmr analysis, it was possible to distinguish between CH_3OCD_3 and CH_3OD reaction products and thereby show that deuterioxide ion does not compete with methoxide ion in the cleavage of 3-methoxypyridine. With 4-methoxypyridine, methoxyl group exchange is faster than the formation of 4-hydroxypyridine. 3-Methoxypyridine undergoes hydrogen–deuterium exchange in the order H-4 > H-5 > H-2; no exchange at H-6 was observed. Hydrogen–deuterium exchange took place at H-3,5 but not at H-2,6 of 4-methoxypyridine. At 218°, 3-chloro- and 3-bromopyridine react with sodium methoxide to give 3-methoxypyridine which then undergoes ether cleavage. The concentrations of all pyridines in the consecutive reactions were followed by nmr. The ratios of the second-order rate constants for methoxy dehalogenation and ether cleavage at 218° are 0.53 and 0.75, respectively. Reactions leading to hydroxy compounds are of preparative value. No evidence was found for the formation of 3,4-pyridyne by dehydro halogenation of the halopyridines.

The preferred general method of cleaving ethers continues to involve the use of a strong acid.[1,2] Cleavage of ethers by bases, however, is regarded more as a curiosity, if not as an undesirable side reaction.[3] It has been suggested that cleavage of ethers by alcoholic KOH is of no preparative value.[4]

We wish to report the results of some preparative and kinetic studies of the methoxide ion induced cleavage of pyridyl methyl ethers. These studies were designed to (1) show that the cleavage reaction is of preparative value, (2) provide evidence for the expected SN2 mechanism, (3) obtain a measure of the ability of the aryl group to influence reactivity, (4) determine whether in a methanol–water mixture hydroxide ion competes with methoxide ion, and (5) determine the ability of a polar, aprotic solvent to influence the rate of ether cleavage.

We also report that 3-chloro- and 3-bromopyridine undergo methoxy dehalogenation at rates slightly slower than the accompanying ether cleavage.

Results and Discussion

Ether Cleavage.—3-Methoxypyridine undergoes cleavage by sodium methoxide in methanol and also in dimethyl sulfoxide (DMSO). That the anion of 3-hydroxypyridine was being formed was established by comparison with an authentic sample. The formation of methyl ether was established by mass spectrometry; this substance was distilled at 0° from a DMSO reaction mixture and characterized by its mass spectrum. It was possible to follow the disappearance of the methoxypyridine quantitatively using nmr because peaks of 3-hydroxypyridine anion are shifted upfield with respect to the starting material.

In principle, 3-methoxypyridine may undergo a cleavage reaction involving not only methoxide ion but also hydroxide ion.[5] Hydroxide ion is present in methanol–sodium methoxide when the methanol is not anhydrous[6] (eq 1). Since it is difficult to remove all

$$CH_3O^- + H_2O \rightleftharpoons CH_3OH + OH^- \quad (1)$$

traces of water from methanol, we attempted to determine whether hydroxide ion was responsible for a part of the cleavage. This was done using CD_3OD–CD_3ONa and CD_3OD–CD_3ONa–D_2O. Use of a deuterio rather than a proteo solvent makes it possible to employ nmr to identify cleavage products containing a methoxyl group. In proteo methanol signals for these products overlap with those of the solvent.

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