of C_2O to yield C and CO seems very probable, since it may well absorb strongly there even though ketene does not. Carbon suboxide itself, which may be a stronger analog to C_2O than is ketene, does absorb strongly in this region.

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RECEIVED NOVEMBER 1, 1961

SELECTIVITY IN SOLVOLYSES CATALYZED BY POLY-(4-VINYLPYRIDINE)[1]

Sir:

Selectivity in enzymatic reactions apparently arises from the preferential binding, by electrostatic or secondary valence forces, of the substrate to the catalyst prior to the covalent changes in the substrate. As a simple model[2] for an enzyme system we chose for study poly-(4-vinylpyridine). In weakly acidic solutions this polymer would possess both cationic sites, which by electrostatic attraction should bind anionic substrates to the polymer,[3] and basic nitrogen atoms, which in low molecular weight compounds are known to catalyze the hydrolysis of nitrophenyl esters.[4] 2,4-Dinitrophenyl acetate (DNPA) and potassium 3-nitro-4-acetoxybenzenesulfonate (NABS) were employed as substrates, the former to illustrate the behavior of an uncharged substrate and the latter to reveal the effect of charge interaction between a poly-ion and a substrate counter ion on the course of a catalyzed solvolysis. For comparison purposes solvolyses catalyzed by 4-picoline, a model for the repeating unit of the polymer, also were examined.

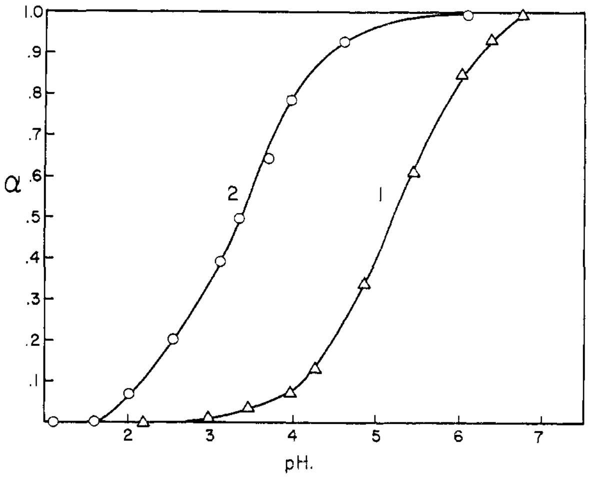

Fig. 1.—Titration curves for 4-picoline, Δ (curve 1), and poly-(4-vinylpyridine), O (curve 2), in 50% (v./v.) ethanol-water, 0.04 M in KCl at 36.6°.

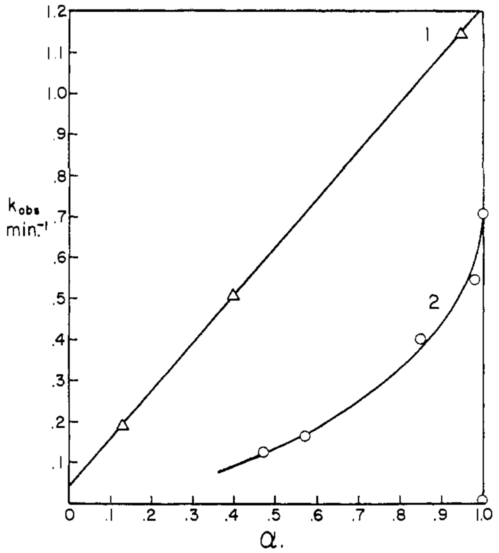

Fig. 2.—Solvolysis of 2,4-dinitrophenyl acetate catalyzed by 0.0157 M 4-picoline, Δ (curve 1), and by 0.010 base molar poly-(4-vinylpyridine), O (curve 2).

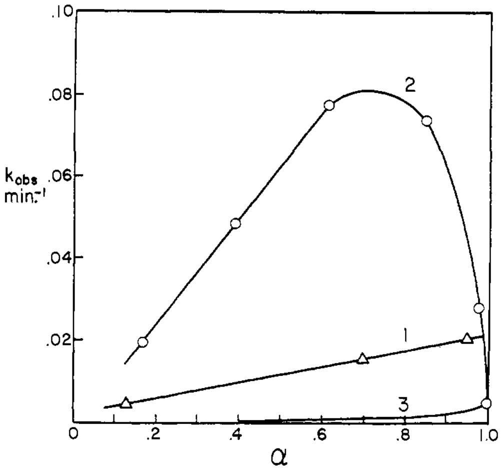

Fig. 3.—Solvolysis of potassium 3-nitro-4-acetoxybenzenesulfonate catalyzed by 0.0157 M 4-picoline, Δ (curve 1) and by 0.010 base molar poly-(4-vinylpyridine), O curve 2.

The reactions were carried out at 36.6° in 50% (v./v.) ethanol-water which was 0.04 M in potas-

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[1] This research was supported in part by a grant from the National Science Foundation, G7414.

[2] J. R. Whitaker and F. E. Deatherage, *J. Am. Chem. Soc.*, **77**, 3360, 5298 (1955), found that glycylcycine hydrolyzed faster than acetylglycine with Dowex-50 as a catalyst but more slowly than acetylglycine in hydrochloric acid solution. The Dowex resin was insoluble in water and it may be assumed that the basic peptide was preferentially held in the acid medium within the resin particles. Attempts to attain selectivity with homogeneous catalysts have been less successful. M. L. Bender and Y. L. Chow, *ibid.*, **81**, 3929 (1959), observed that the 2-aminopyridinium ion appeared to be unusually effective as a catalyst in the hydrolysis of o-nitrophenyl oxalate anion. The result could be ascribed to "electrostatic catalysis"; however, as pointed out by Bender, an ambiguity exists in the interpretation of this experiment for a reaction of the nitrophenyl oxalate anion with the aminopyridinium ion cannot be distinguished kinetically from a reaction of nitrophenyl hydrogen oxalate with 2-aminopyridine.

[3] Numerous studies of counter ion binding by polyelectrolytes have been reported. See for example, F. T. Wall and W. B. Hill, *J. Am. Chem. Soc.*, **82**, 5599 (1960); F. T. Wall and M. J. Eitel, *ibid.*, **79**, 1550, 1556 (1957); I. Kagawa and K. Katsuura, *J. Poly Sci.*, **17**, 365 (1955); H. P. Gregor and D. H. Gold, *J. Phys. Chem.*, **61**, 1347 (1957); P. Doty and G. Ehrlich, *Ann. Rev. Phys. Chem.*, III (1952). It is noteworthy that H. Ladenheim, E. M. Loebl, and H. Morawetz, *J. Am. Chem. Soc.*, **81**, 20 (1959), found that poly-(4-vinylpyridine) functioned selectively in a non-catalytic reaction, the quaternization with α-bromoacetamide and with bromoacetate ion.

[4] See M. L. Bender, *Chem. Rev.*, **60**, 53 (1960), for a review of hydrolytic reactions catalyzed by pyridine, imidazole, and related nucleophiles.

sium chloride, 0.01 base molar in poly-(4-vinylpyridine)[5] or 0.0157 *M* in 4-picoline, and $1-4 \times 10^{-4}$ *M* in substrate. They were followed with a Cary spectrophotometer by the change in absorbance at 360 mμ. The products, 2,4-dinitrophenol and potassium 3-nitro-4-hydroxybenzenesulfonate, were characterized by their ultraviolet spectra. Good first order kinetics were obtained with DPNA in all cases and with NABS in the more acidic solutions. Some curvature was noted in the first order plots for reactions of NABS catalyzed by poly-(4-vinylpyridine) at pH values greater than 4; in these cases the reported rate constants correspond to the first 50% of reaction.[6] The spontaneous solvolyses were very slow relative to those catalyzed by the nitrogen bases (k_{obs} in absence of nitrogen base equalled 0.0004 min.$^{-1}$ for NABS at pH 4.5 and 0.004 min.$^{-1}$ for DNPA at pH 6.5), and in the range tested (0.002–0.02 base molar poly-(4-vinylpyridine), pH 3.6, 2×10^{-4} *M* NABS) the solvolytic rate constants were proportional to the polymer concentration. To assist in interpreting the data, both poly-(4-vinylpyridine) and 4-picoline were titrated with hydrochloric acid, the change in protonation of the bases being followed spectrophotometrically at 254 mμ. A plot of α, the fraction of nitrogen present as the free base, *versus* pH is shown in Fig. 1.

Data for solvolysis of DNPA are presented in Fig. 2. With the 4-picoline buffers, the observed rate constants increased linearly with increasing α, in accordance with data on the hydrolysis of substituted nitrophenyl esters conducted in aqueous solutions.[4] A concave k_{obs}–α plot was obtained for the reaction catalyzed by poly-(4-vinylpyridine). This result may be attributed to a reduction in the nucleophilicity of the nitrogens in the polymer as positive charges accumulate along the polymer chain.

A striking change was observed in the reactions of NABS (Fig. 3). As in the previous case the rate increased linearly with α for the picoline catalyzed reaction; however, for the solutions which contained poly-(4-vinylpyridine) the solvolytic rates *increased* as the pH was lowered and a maximum in the k_{obs}–α plot was attained near α = 0.6 (pH 3.6). The enhancement in the rates of the polymer catalyzed reaction may be rationalized on the basis that protonated nitrogen sites serve to attract or bind a negatively charged substrate (NABS) to the polymer coil where basic nitrogen sites are available to catalyze the solvolysis. Solvolyses of electrically neutral molecules such as DNPA are not subject to this binding. An estimate of the contribution of binding to the catalytic rate may be obtained from k_{obs} for $\alpha = 1$ (pH 6.5, curve 2, Fig. 3), where essentially only conventional nucleophilic catalysis should operate, and curve 2, Fig. 2. On the assumption that curve 2 for the DNPA solvolysis provides a measure of the nucleophilicity of poly-(4-vinylpyridine) in acid solution, one may derive curve 3, Fig. 3, which represents the values of k_{obs} that would be expected if poly-(4-vinylpyridine) functioned only in the conventional sense. The difference between curves 1 and 3, Fig. 3, accordingly indicates the extent of reaction associated with ionic interaction between substrate and catalyst.

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[5] The polyvinylpyridine was prepared by the method of E. G. Fitzgerald and R. M. Fuoss, *Ind. Eng. Chem.*, **42**, 1603 (1950); the molecular weight was 60,000 (from viscosity).

[6] The values corresponding to higher conversions would be less.

[7] Hercules Powder Company Fellow, 1958; Public Health Service Research Fellow, 1960.

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RECEIVED NOVEMBER 13, 1961

A SYNTHESIS OF D-NORSTEROIDS

Sir:

Modified steroids are known in which the A, B, or C-ring of the normal steroid skeleton either has been contracted or reconstituted from a cleavage product into a cyclopentane ring.[1] A procedure is now described for the conversion of 17-ketosteroids to norsteroids containing a four-membered D-ring. No examples of such D-norsteroids have been reported previously.[2]

Base-catalyzed nitrosation of estrone methyl ether (I) gave 16-oximinoestrone methyl ether (II),[3] converted by chloramine in aqueous tetrahydrofuran, in 81% yield, to 16-diazoestrone methyl ether (III), m.p. 145–146°.[4] Irradiation of III with ultraviolet light (low pressure argon source) in aqueous tetrahydrofuran containing sodium bicarbonate gave, after acidification, the noracid IV, m.p. 188–189°, in 63% yield. The carboxyl group of acid IV, assigned the β-configuration on mechanistic grounds,[5] was converted by diazomethane to the methyl ester V, m.p. 103–104°. Since the hydrogen alpha to the carbomethoxy group in V was neither epimerizable by base nor unambiguously detectable by nuclear magnetic resonance, its presence was confirmed indirectly.

Reduction of acid IV with lithium aluminum hydride gave, in 78% yield, alcohol VI, m.p. 141–142°. Reaction of VI with methanesulfonyl chloride gave, in 72% yield, mesylate VII, m.p. 154–155°. Reaction of mesylate VII with sodium thiophenolate in warm dimethylsulfoxide gave, in 75% yield, the sulfide VIII, m.p. 111–112°. Desulfurization of VIII with Raney nickel in ethanol afforded, in 68% yield, substance IX, m.p. 50–51°. Kuhn–Roth oxidation of IX gave 1.56 equivalents of acetic acid, ruling out the possibility that both C-methyls in the molecule might be attached to the same carbon atom. The nuclear magnetic resonance spectrum of IX confirmed this conclusion, and showed one unsplit tertiary methyl at 9.11τ

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[1] For examples involving rings A, B, and C, respectively, see: (a) F. L. Weisenborn and H. E. Applegate, *J. Am. Chem. Soc.*, **81**, 1960 (1959); (b) F. Sorm and H. Dykova, *Coll. Czech.*, **13**, 407 (1948); (c) N. L. Wendler, R. F. Hirschmann, H. R. Slates, and R. W. Walker, *J. Am. Chem. Soc.*, **77**, 1632 (1955).

[2] Further examples of this class, obtained independently by the same general method as that outlined here, are described in the accompanying communication: J. Meinwald, G. G. Curtis and P. G. Gassman, *J. Am. Chem. Soc.*, **84**, 116 (1962).

[3] F. Litvan and R. Robinson, *J. Chem. Soc.*, 1997 (1938).

[4] Melting points are uncorrected. Satisfactory analyses were obtained for all compounds whose melting points are reported.

[5] J. Meinwald and P. G. Gassman, *J. Am. Chem. Soc.*, **82**, 5445 (1960).