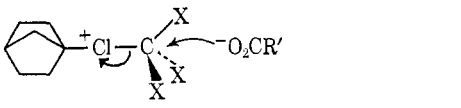
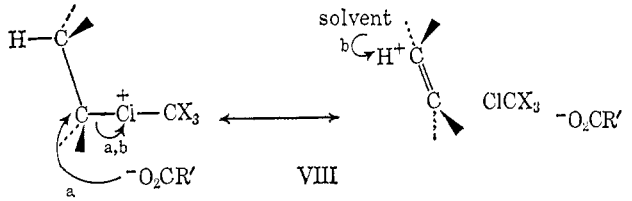
the cleavage of the C–N bond might be the critical factor. The formation of species such as VI could also account for the intramolecular inversion observed in nonbridgehead deaminations.[14,15]

The formation of 1-norbornyl chloride can be represented as in VII. A discrete coordination compound is probably formed in view of the decrease in chloride abstraction in the solvent series dichloromethane, chloroform, carbon tetrachloride; if CH_2Cl^+, $CHCl_2^+$, and CCl_3^+ were formed, the order would presumably have been reversed.[16] Nonbridgehead carbonium ions have other reaction modes available (VIIIa and b). Path VIIIb is apparently dominant in



VII



VIII

view of the large amounts of olefin obtained from amines with β hydrogens (*sec*-butyl → ~50% olefins with little or no *sec*-butyl chloride; in benzene, the decomposition yields only a few per cent *sec*-butylbenzene).[17] The nitroso amide decomposition of benzhydrylamine also shows a low chloride abstraction,[18] either because of the importance of path VIIIa or more probably because of the low potential of the benzhydryl carbonium ion.

The present results indicate that considerable disorder occurs in the nitro amide and carbamate decompositions described. In view of the similarity in the nitro amide, nitroso amide, triazene, and nitrous acid methods of deamination,[11,19,20] it is probable that a similar disorder leading to solvent-derived products will also be found for the other methods of deamination.

Acknowledgment. The authors are grateful for support of this work by the National Science Foundation (GP-5446).

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(15) E. H. White and F. W. Bachelor, *Tetrahedron Letters*, 75 (1965).
(16) P. Petrenko-Kritschenko and V. Opotsky, *Chem. Ber.*, **59B**, 2131 (1926), cited in J. Hine, "Physical Organic Chemistry," 2nd ed, McGraw-Hill Book Co., Inc., New York, N. Y., 1962, p 485.
(17) Low yields of alkylated aromatics have been reported for aprotic diazotization of aliphatic amines (A. T. Jurewicz, J. H. Bayless, and L. Friedman, *J. Am. Chem. Soc.*, **87**, 5788 (1965). The larger amounts reported from the reaction of isocyanates with nitrosonium hexafluoroantimonate (G. A. Olah, N. Friedman, J. M. Bollinger, and J. Lukas, *ibid.*, **88**, 5328 (1966)) probably arise from direct ionization or from the carbonium hexafluoroantimonate ion pairs. After this paper was submitted, a report on the alkylation of aromatic solvents by bridgehead carbonium ions derived in various ways was reported by P. Beak and R. J. Trancik (*ibid.*, **90**, 2714 (1968)).
(18) E. H. White and C. A. Elliger, *ibid.*, **89**, 165 (1967).
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(20) H. Maskill, R. M. Southam, and M. C. Whiting, *Chem. Commun.*, 496 (1965).

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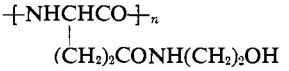
Circular Dichroism of Polypeptides. Poly(hydroxyethyl-L-glutamine) Compared to Poly(L-glutamic acid)

Sir:

Optical rotatory dispersion (ORD)[1] and, more recently, circular dichroism (CD)[2] have become valuable tools for studying polypeptide and protein conformations. For reasons of water solubility, most previous work has focused upon polypeptides with ionizable side chains; these polymers show similar rotatory properties in the "random coil" form when their side chains bear charges. The present report compares such a polyelectrolyte, poly(L-glutamic acid) (PGA),[1,2] with water-soluble, nonionizable poly[N^5-(2-hydroxyethyl)-L-glutamine] (PHEG). PHEG is randomly coiled in water and α helical in aqueous methanol.[3] PGA and PHEG α helices are seen to have similar CD spectra, whereas the ellipticities of the "unordered" forms are significantly different.



PGA sodium salt was purchased from Pilot Chemicals, lot G32, degree of polymerization 610. PHEG was synthesized by the method of Lupu-Lotan, *et al.*,[4] and had a specific viscosity 0.59 (0.2% in 0.2 *M* NaCl).

CD and ORD measurements were made on a Cary 60 recording spectropolarimeter at 22°. Cells of path length 0.1–10 mm were used. All solutions were unbuffered; pH was adjusted with 0.1 *M* HCl. Polymer concentrations were varied between 0.01 and 0.2% for each choice of solvent conditions and were determined by micro-Kjeldahl analysis. Each curve shown in the figures represents an average of at least five experiments. Signal-to-noise ratios always exceeded 20. Wavelength readings were reproducible to ±0.5 mμ. No wavelength shifts were observed, for a given polypeptide and conformation, as pH and concentration of salt and polymer were varied.

ORD curves for PHEG in the helical (——) and coiled (·····) forms are shown in Figure 1. The data extend to lower wavelength and are similar at high wavelength to the results of Lupu-Lotan, *et al.*[3] The magnitudes of the PHEG coil Cotton effects are lower than those reported for PGA.[1] The coil-to-helix transition occurring as the methanol concentration is increased was followed by measuring $[m']_{233}$. The plot obtained was superposable upon that of b_0 *vs.* per cent methanol.[3]

Figure 2 presents CD data for PHEG; 95% methanol was chosen to ensure complete helicity. Residue ellipticities, $[\theta]$, were completely independent of PHEG

(1) The ORD literature is reviewed by J. T. Yang in "Poly-α-Amino Acids: Protein Models for Conformational Studies," G. D. Fasman, Ed., Marcel Dekker, Inc., New York, N. Y., 1967.
(2) The CD literature is reviewed in: (a) S. Beychok in "Poly-α-Amino Acids: Protein Models for Conformational Studies," G. D. Fasman, Ed., Marcel Dekker, Inc., New York, N. Y., 1967; (b) S. N. Timasheff, H. Susi, R. Townend, L. Mescanti, M. J. Gorbunoff, and T. F. Kumosinski in "Conformations of Biopolymers," Vol. 1, G. N. Ramachandran, Ed., Academic Press, New York, N. Y., 1967; (c) J. T. Yang in "Conformations of Biopolymers," Vol. 1, G. N. Ramachandran, Ed., Academic Press, New York, N. Y., 1967.
(3) N. Lupu-Lotan, A. Yaron, and A. Berger, *Biopolymers*, **4**, 365 (1966).
(4) N. Lupu-Lotan, A. Yaron, A. Berger, and M. Sela, *ibid.*, **3**, 625 (1965), and personal communication.

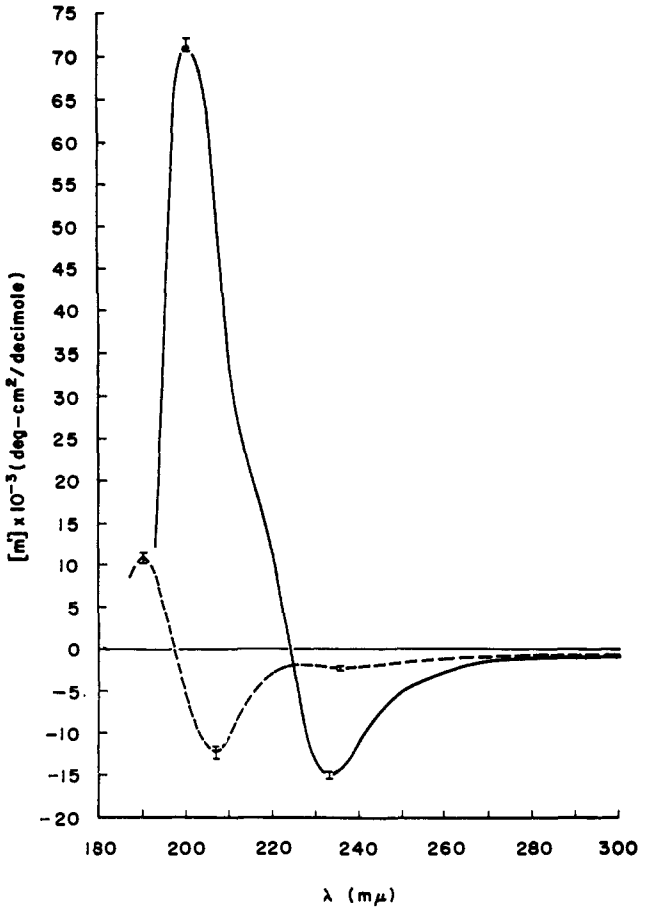


Figure 1. Optical rotatory dispersion of PHEG: in methanol-water, 8:2, ———; in water, ---------.

concentration, for both helix and coil.[5] CD curves for PGA are given in Figure 3.

A comparison of the CD spectra for PGA and PHEG in the "random coil" shows that the magnitudes of the peaks at 217 and 197 mμ are much larger for PGA. In water, $[\theta]_{217}$ +2200 ± 100, $[\theta]_{198}$ −26,400 ± 1100 for PHEG; however, $[\theta]_{217}$ +6200 ± 700, $[\theta]_{197}$ −36,900 ± 3300 for PGA (sodium salt). The similar transition wavelengths for the two polymers suggest that similar electronic interactions among peptide chromophores are responsible for the CD spectra in both cases. However, the differences in dichroic magnitudes may indicate that the highly charged PGA coil is more extended and, hence, more asymmetric than the uncharged PHEG. This explanation is supported by the fact that salts decrease the magnitudes of the 217- and 197-mμ CD peaks for PGA, presumably by shielding charges and allowing the coil to contract somewhat (0.2 *M* NaF had the same effect as the $NaClO_4$ shown in Figure 3). A similar effect of salt upon the viscosity and ORD of charged PGA has been reported.[6] The CD of charged PGA is independent of concentration. One curious point is that the small negative CD peak above 230 mμ is larger for PHEG than for PGA, and

(5) Peak values (in degrees cm²/decimole) of reduced residue ellipticity, corrected for refractive index, are: PHEG helix, $[\theta']_{221}$ −33,600, $[\theta']_{209}$ −34,000, $[\theta']_{193}$ +78,600; PGA helix in water, $[\theta']_{222}$ −30,800, $[\theta']_{209}$ −27,200, $[\theta']_{191}$ +68,500; PHEG coil, $[\theta']_{233}$ −630, $[\theta']_{217}$ +1700, $[\theta']_{198}$ −19,600; PGA coil in water, $[\theta']_{238}$ −180, $[\theta']_{217}$ +4700, $[\theta']_{197}$ −27,400.

(6) E. Iizuka and J. T. Yang, *Biochemistry*, 4, 1249 (1965).

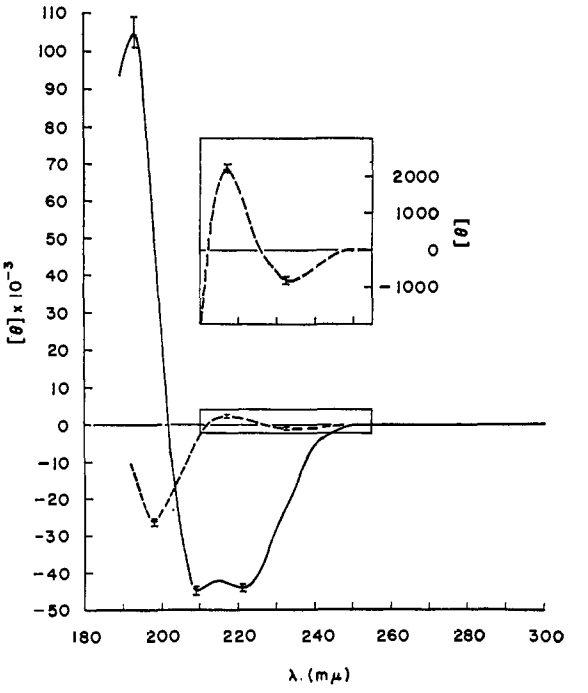


Figure 2. Circular dichroism of PHEG: in methanol-water, 95:5, ———; in water, --------- Inset shows random coil data for 212–255 mμ on expanded scale.

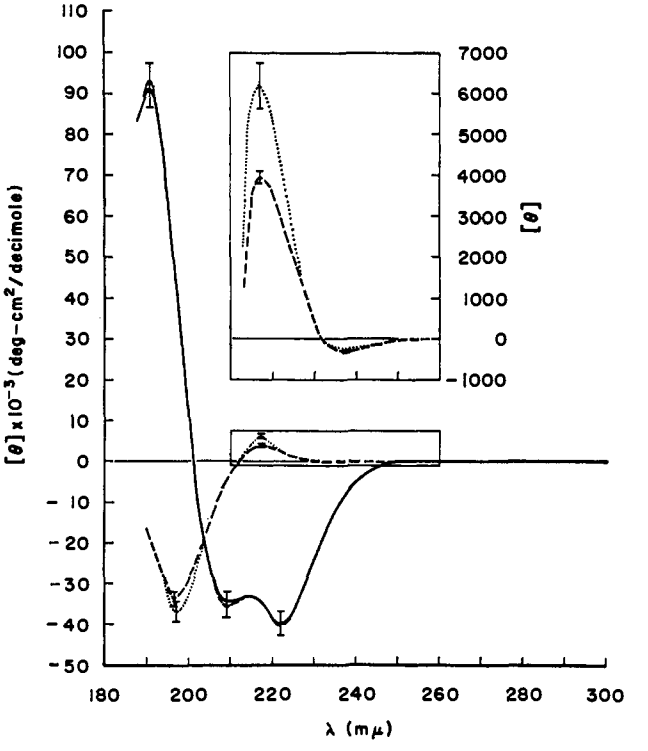


Figure 3. Circular dichroism of PGA: pH 4.3 in 0.2 *M* $NaClO_4$, ———; pH 4.4 in water, -·-·-·; pH 7.4 in 0.2 *M* $NaClO_4$, ---------; pH 7.5 in H_2O, ·····. Inset similar to that in Figure 2.

greater in salt than in water for PGA; the assignment of this band is not certain.[2] The present study shows that caution should be exercised in speaking of "random coil" or "unordered" forms of polypeptides; the conformation and optical parameters can vary with polymer and conditions.[7]

The α-helical forms of PHEG and PGA display similar CD spectra,[8] as shown in Figures 2 and 3. Dilute salt has little effect upon the CD of PGA at pH 4.4. Helix formation is complete at this pH.[9] All three CD peaks of PGA enlarge (by approximately the same amount) as the PGA concentration increases. For example, $[\theta]_{222}$ in water averages $-37{,}600$ for the concentration range 0.01–0.03% PGA, $-40{,}800$ for 0.04–0.08%, and $-43{,}100$ for 0.09–0.20%. Each range includes seven different concentrations, average errors are ± 2000, and readings did not change with time. Somewhat less concentration dependence was noticed in 0.2 *M* salt. The observed effect of PGA concentration upon CD can be attributed to aggregation of helices.[9-12]

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(7) Furthermore, the "random coil" forms undergo additional change upon heating. At pH 7.7 in 0.2 *M* $NaClO_4$, $[\theta]_{198}$ for both PHEG and PGA gradually decreases, reaching the same limiting value of $-16{,}000$ for both polymers at 90°.

(8) The differences between these CD spectra are within experimental error. However, the differences are of the type noted as a helix solvent effect by F. Quadrifoglio and D. W. Urry, *J. Am. Chem. Soc.*, **90**, 2755 (1968).

(9) J. T. Yang and W. J. McCabe, *Biopolymers*, **3**, 209 (1965).

(10) T. M. Schuster, *ibid.*, **3**, 681 (1965).

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(12) Y. Tomimatsu, L. Vitello, and W. Gaffield, *Biopolymers*, **4**, 653 (1966).

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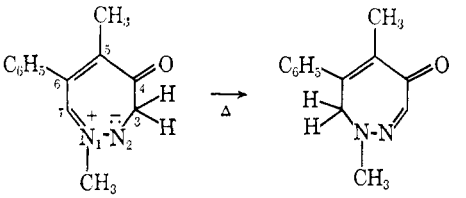
Heterocyclic Studies. XXVIII. Sigmatropic and Electrocyclic Reactions in the 1,2-Diazepine System. Formation of a 1,7-Diazabicyclo[4.1.0]heptenone[1]

Sir:

We wish to report novel examples of a sigmatropic rearrangement and an electrocyclic reaction occurring in a seven-membered heterocyclic ring and isolation from the latter reaction of a [4.1.0] valence isomer of the 1,2-diazepine system. Reactions of this bicyclic product have clarified the mechanism of several rearrangements previously observed in this series.

The 1,2-diazepinium betaine **1**, obtained by methylation of the 2,3-dihydrodiazepinone,[2,3] rearranges on standing in the solid state or in solution to the 1-methyl-1,7-dihydrodiazepinone **2**.[4] We have now found that in $CDCl_3$–CD_3OD solution no significant deuterium exchange occurs on conversion of **1** to **2**; the nmr spectrum of **2** showed signals for C–Me, N–Me, 7-CH_2, and 3-CH in intensity ratio 3.0:3.0:1.9:1.0. The rate constants, determined spectrophotometrically in methanol and chloroform, and kinetic parameters are given in Table I.



1 2

The absence of deuterium in the diazepinone **2** obtained in the presence of CD_3OD, the somewhat higher rate in a nonprotic solvent, and the magnitude of the activation energy indicate that the transformation is not a prototropic tautomerization, as previously suggested,[3] but rather a concerted intramolecular process, *i.e.*, a thermally allowed 1,5-sigmatropic hydrogen shift of a type well precedented in the cycloheptatriene series.[5]

Table I. First-Order Rate Constants (k_1)[a] and Activation Parameters for the Thermal Rearrangement **1** → **2**

Solvent	$k_1 \times 10^4$ sec^{-1}, 25.0 ± 0.1°	$k_1 \times 10^4$ sec^{-1}, 35.0 ± 0.1°	E_a, kcal/mol	$\Delta S^{\ddagger}$, eu
CH_3OH	2.4	6.0	+17	−21
$CHCl_3$	3.0	9.0	+20	−9

[a] Plotted by the Guggenheim method.

To examine the possibility of a 1,3-sigmatropic rearrangement in the photoexcited state, a solution of the betaine **1** in methanol–chloroform was exposed to sunlight at −80°. After 35 min, **1** had disappeared and the solution was evaporated to an oil which was chromatographed on silicic acid. The initial fraction contained a trace of the 1,5-dihydrodiazepinone **3**[6] (~2% yield), identified by the nmr spectrum [δ 1.05 (d, J = 7 Hz), 3.70 (s), 6.65 (s)]. The major product (80% yield by nmr of crude mixture, 70% by weight of chromatographic fractions) crystallized as off-white prisms: mp 72–75°; ν_{CO}^{KBr} 1665 cm^{-1}; λ_{max}^{MeOH} 278 mμ (ε 11,000), 342 (shoulder); nmr ($CDCl_3$) δ 1.85 (s, 3), 2.62 (s, 3), 3.20 (s, 1), 3.64, 3.96 (dd, AB J = 18 Hz), 7.43 (s, 5). *Anal.* Calcd for $C_{13}H_{14}ON_2$: C, 72.87; H, 6.59; N, 13.08. Found: C, 73.16; H, 6.67; N, 13.09. The compound could be sublimed to give pale yellow crystals, but exposure of the solid to light caused a deep carmine coloration on the surface due to a photochromic effect.

The spectral properties of this photoisomer clearly reveal the structure as 4,7-dimethyl-5-phenyl-1,7-diazabicyclo[4.1.0]-4-hepten-3-one (**4**), arising by a concerted 4π electrocyclic reaction of the azomethine imine system in **1**. A related photocyclization has recently been postulated in the conversion of a 1-iminopyridinium betaine to 1-ethoxycarbonyl-1,2-diazepine,[7] but the diaziridine was not isolated. The 1,5-dihydrodiazepinone **3** is presumably the product of a competing 4π sigmatropic rearrangement of **1**, but formation of a trace of **3** by thermal rearrangement of **1** to **2** and subsequent photochemical conversion of **2** to **3** cannot be excluded. A third product present in the more polar fractions of the photolysis mixture (~25% by nmr) was the 6-methylaminopyridine **5**.[3] This pyridine

(1) Supported by Grant GP-5219 from the National Science Foundation.

(2) J. A. Moore and J. Binkert, *J. Am. Chem. Soc.*, **81**, 6029 (1959).

(3) W. J. Theuer and J. A. Moore, *J. Org. Chem.*, **32**, 1602 (1967).

(4) J. A. Moore and W. J. Theuer, *ibid.*, **30**, 1887 (1965).

(5) For leading references, *cf.* J. A. Berson, *Accounts Chem. Res.*, **1**, 152 (1968).

(6) M. G. Pleiss and J. A. Moore, *J. Am. Chem. Soc.*, **90**, 1369 (1968).

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