

4.49, 4.63, and 3.92);  $\lambda_{\text{max}}^{\text{MeOH}-0.01\text{NNaOH}}$  232, 266, 340, and 418  $\mu$  ( $\log \epsilon$  4.45, 4.53, 3.77, and 4.08).

Unusual features of the tautomerism of II and the stability of III have been discussed previously.<sup>4</sup>

(4) L. H. Conover, Special Publication No. 5, The Chemical Society, London, 1956, p. 48.

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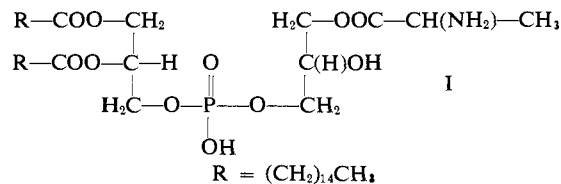
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## Synthesis of Amino Acid-Esters of Phosphatidylglycerols

Sir:

Various investigators have reported the formation of lipoamino acid complexes in tissue preparations and in microorganisms.<sup>1-7</sup> Apart from the fact that these complexes were usually found in the phospholipid fractions, little was known regarding their chemical structure. Recently, MacFarlane reported<sup>8</sup> that the phospholipid fraction in a batch of *Clostridium welchii* was bound almost entirely to amino acids, and she presented experimental evidence which suggests strongly that the lipoamino acid complexes are amino acid esters of phosphatidylglycerol. The phosphatidyl moiety of the lipoamino acid complexes is presumed to have the same structure and configuration as in phosphatidylglycerol. The amino acids, which were found to consist of alanine, glutamic acid, aspartic acid, lysine, and possibly arginine and histidine, were arbitrarily assigned the terminal position in the fatty-acid-free glycerol moiety. Further evidence, supporting the structure proposed by MacFarlane, was reported by Sinha, Fogel, and Gaby<sup>9</sup> and Vorbeck and Marinetti.<sup>10</sup> However, without definite knowledge of the position of the amino acids in these complexes proof of the structure cannot be considered complete. For this reason, we have synthesized an alanine ester of  $\alpha$ -(L- $\alpha$ -phosphatidyl)glycerol having the structure proposed by MacFarlane for the lipoamino acid complexes.<sup>8</sup> In it the amino acid is attached to the terminal hydroxyl of the fatty-acid-free glycerol moiety (formula I). The compound was obtained *via* the following



(1) R. W. Hendler, *Science*, **128**, 143 (1958).

(2) R. W. Hendler, *J. Biol. Chem.*, **234**, 1473 (1959).

(3) W. L. Gaby, R. N. Naughten, and C. Logan, *Arch. Biochem. Biophys.*, **82**, 38 (1959).

(4) W. L. Gaby, H. L. Wolin, and I. Zajac, *Cancer Res.*, **20**, 1508 (1960).

(5) W. L. Gaby and R. Silberman, *Arch. Biochem. Biophys.*, **87**, 188 (1960).

(6) G. D. Hunter and R. A. Goodsall, *Biochem. J.*, **74**, 34P (1960).

(7) G. D. Hunter and R. A. Goodsall, *ibid.*, **78**, 564 (1961).

(8) M. G. MacFarlane, *Nature*, **196**, 136 (1962).

(9) D. B. Sinha, S. Fogel, and W. L. Gaby, *Federation Proc.*, **23**, 221 (1964).

(10) M. L. Vorbeck and G. V. Marinetti, *ibid.*, **23**, 375 (1964).

series of intermediates:  $\alpha, \gamma$ -benzylideneglycerol  $\rightarrow$   $\alpha, \gamma$ -benzylidene- $\beta$ -benzylglycerol  $\rightarrow$   $\beta$ -benzylglycerol  $\rightarrow$   $\alpha$ -azidopropionyl- $\beta$ -benzylglycerol [ $n^{25}_D$  1.5147,  $d^{25}_4$  1.180. *Anal.* Calcd. for  $\text{C}_{13}\text{H}_{17}\text{O}_4\text{N}_3$ : C, 55.90; H, 6.13; N (Kjeldahl), 5.02; N (Dumas), 15.04. Found: C, 56.10; H, 6.06; N (Kjeldahl), 4.60; N (Dumas), 14.05]  $\rightarrow$   $\alpha$ -(dipalmitoyl-L- $\alpha$ -glycerylphosphoryl)- $\beta$ -benzyl- $\alpha'$ -(2-azidopropionyl)glycerol [m.p. 27.5-28.5°,  $[\alpha]^{25}_D + 2.9^\circ$  (c 10, chloroform). *Anal.* Calcd. for  $\text{C}_{54}\text{H}_{88}\text{O}_{11}\text{N}_3\text{P}$ : C, 65.76; H, 8.99, P, 3.14, N (Kjeldahl), 1.42; N (Dumas), 4.26. Found: C, 65.41; H, 8.81; P, 3.06; N (Kjeldahl), 1.37; N (Dumas), 4.63]  $\rightarrow$   $\alpha$ -(dipalmitoyl-L- $\alpha$ -glycerylphosphoryl)- $\alpha'$ -(2-aminopropionyl)glycerol [m.p. 164-165°, meniscus formation,  $[\alpha]^{25}_D + 6.6^\circ$  (c 10, chloroform). *Anal.* Calcd. for  $\text{C}_{41}\text{H}_{80}\text{O}_{11}\text{NP}$ : C, 62.01; H, 10.16; N (Kjeldahl), 1.76; N (Dumas), 1.76; P, 3.90. Found: C, 62.16; H, 9.98; N (Kjeldahl), 1.73; N (Dumas), 1.86; P, 3.81].

The synthesis of the corresponding glycine ester of L- $\alpha$ -phosphatidyl- $\alpha$ -glycerol is in progress in this laboratory.

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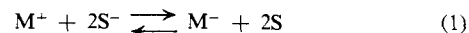
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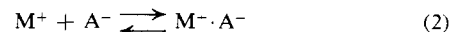
## Conjecture on the Composition of Dilute Alkali Metal-Ammonia Solutions

Sir:

There is evidence from calculated values of the electron affinities of the alkali metals<sup>1</sup> that their anions should be stable in the gas phase. This stability should be enhanced in polar solvents as the result of ionic solvation.<sup>2</sup> For this reason, we conjecture that such solvated anionic species are constituents of solutions of the alkali metals in liquid ammonia. We propose that these species are involved in an oxidation-reduction equilibrium (eq. 1) involving solvated metal



cations and solvent where all species are assumed to be solvated,  $\text{M}^+$  is the metal cation, S is the solvent,  $\text{M}^-$  is the metal anion, and  $\text{S}^-$  is a solvent anion, *i.e.*, solvated electron. In addition, we propose that ion pairing occurs according to



where  $\text{A}^-$  is either  $\text{S}^-$  or  $\text{M}^-$ . For dilute solutions, to which we restrict ourselves, the presence of higher ionic multiples may be disregarded.<sup>3</sup>

By assuming that ion pairing is nonspecific, that the related equilibrium constant  $K_2$  is given by Fuoss'

(1) E. Clementi, *Phys. Rev.*, **133**, A1274 (1964).

(2) R. M. Noyes, *J. Am. Chem. Soc.*, **84**, 513 (1962).

(3) Estimates of ion triples by the Bjerrum-Kraus-Fuoss theory (R. M. Fuoss and C. A. Kraus, *ibid.*, **55**, 2387 (1933)) would indicate that these species are relatively unimportant for concentrations of total metal less than *ca.* 0.1 M.

theory,<sup>4</sup> and that the mean ionic activities can be adequately approximated by extended Debye-Hückel theory with an interionic size parameter of 5.5 Å,<sup>5</sup> we have determined the equilibrium constant for the oxidation-reduction reaction by fitting to the magnetic susceptibility data of Hutchison and Pastor.<sup>6</sup> For solutions of sodium in liquid ammonia less concentrated than *ca.* 0.1 *M*, we find that (assuming the solvent to be at unit activity)

$$\log K_1 (l.^2/g. \text{ mole}^2) = \frac{2.09 \times 10^3}{T} - 3.42$$

where *T* is the absolute temperature. The equilibrium constants at each temperature, determined for each measured susceptibility, showed no trends with changing metal concentration and gave a mean value with an average deviation of *ca.* 15%. An analogous treatment of potassium solutions also has been made.

With no further adjustments of parameters implicit in *K*<sub>2</sub> and the relevant activity coefficients, calculations were made at a variety of compositions to test the validity of the proposed equilibria as follows.

(1) The vapor pressure depression data of Kraus<sup>7</sup> were compared with calculated values. The maximum deviation obtained for solutions <0.1 *M* was *ca.* 5%, with a trend toward better agreement for the smaller concentrations.

(2) The dilute solution conductance data have been found by others<sup>8</sup> to yield a value of *K*<sub>2</sub> substantially in accord with the value obtained from Fuoss' theory and indicating support for ion pairing. From the calculated temperature coefficient of composition, an estimate of *ca.* 3 × 10<sup>-2</sup> deg.<sup>-1</sup> was obtained for the temperature coefficient of conductance at -33°. The experimental value obtained by Gibson and Phipps<sup>9</sup> is 2 × 10<sup>-2</sup> deg.<sup>-1</sup>.

(3) The Knight shift data<sup>10</sup> for N<sup>14</sup> give values which are essentially proportional to the sum of the computed fractions of S<sup>-</sup> and Na<sup>+</sup>·S<sup>-</sup>. The Knight shift data<sup>10</sup> for Na<sup>23</sup> give values which are essentially proportional to the computed fractions of Na<sup>+</sup>·S<sup>-</sup>.

(4) The dominant species (apart from Na<sup>+</sup>) at -65° for total metal concentrations >5 × 10<sup>-3</sup> *M* were calculated to be Na<sup>-</sup> and Na<sup>+</sup>·Na<sup>-</sup>, and these exhibited very nearly a linear variation in concentration with the concentration of total metal. As a result, the following of Beer's law for absorption, observed by Gold and Jolly,<sup>11</sup> is to be expected on the basis that the absorbing species may have broad, overlapping absorption spectra, not necessarily identical. The deviations from Beer's law observed at very long wave lengths correlates, apart from temperature dependence, with calculated fractions of Na<sup>+</sup>·Na<sup>-</sup>, the observed extinction coeffi-

cients being essentially proportional to the latter. A similar result is obtained at -45°.

The species S<sup>-</sup>·Na<sup>+</sup>·S<sup>-</sup> (in our notation) has been suggested<sup>12</sup> as being present in sodium-ammonia solutions. Though formally similar to the Na<sup>-</sup> proposed here, it is quite different. With the aid of the theory of Kraus and Fuoss,<sup>3</sup> and the noted values of *K*<sub>1</sub> and *K*<sub>2</sub>, we have been able to estimate that [Na<sup>-</sup>]/[S<sup>-</sup>·Na<sup>+</sup>·S<sup>-</sup>] > 2500 in sodium-ammonia solutions for temperatures <-23°. The difference in the molal enthalpies of the two species is estimated to be *ca.* 9 kcal. Unless the electronic structure of the ion triple is altered appreciably, it cannot be identified with solvated metal anion introduced here.

A more detailed analysis of the experimental data leading to the above conclusions is currently being prepared for publication.

*Acknowledgment.*—The present work was supported in part by the Office of Naval Research.

(12) See, for example, K. S. Pitzer, "Metal-Ammonia Solutions," W. A. Benjamin, Inc., New York, N. Y., 1964, p. 198.

(13) NDEA Graduate Fellow, 1961-1964; NSF Cooperative Fellow, 1964.

Sidney Golden, Charles Guttman,<sup>13</sup> Thomas R. Tuttle, Jr.

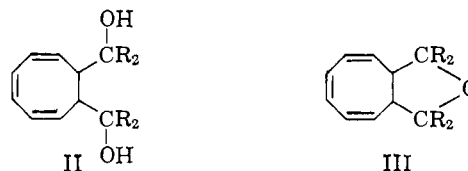
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## Condensation Reactions of Cyclooctatetraene Dianion with Aldehydes and Ketones

Sir:

Cyclooctatetraene dianion (I) is of recent interest with respect to structural theory and its chemical disciplines.<sup>1</sup> It has been reported that dilithium cyclooctatetraenide (I) condenses with aldehydes and ketones such as benzaldehyde, acetone, and benzophenone, etc., to yield 7,8-bis(α-hydroxyalkyl)-1,3,5-cyclooctatrienes (II) which may be dehydrated to tetrahydrofurans (III) by *p*-toluenesulfonic acid.<sup>2</sup> It has been presently found that I reacts with 2 equiv. of these aldehydes and ketones by (1) 1,2-bis addition to give II as probable intermediates which reorganize to 7,8-bis(α-hydroxyalkyl)-bicyclo[4.2.0]octa-2,4-dienes (IV, VI, and VIII) and



1,1,10,10-tetrasubstituted 2,4,6,8-decatetraene-1,10-diols (XII); and (2) 1,4-bis addition to yield 5,8-bis(α-hydroxyalkyl)-1,3,6-cyclooctatrienes (V, X, and XIV). The results thus described illustrate the much greater complexity in condensation reactions of I with carbonyl compounds than previously established<sup>2</sup> and the potential of I as a dicarbanionic reagent of the Grignard type. It has also been found that there are unusual rearrangements and real synthetic utility in acid-catalyzed de-

(1) T. J. Katz, *J. Am. Chem. Soc.*, **82**, 3785 (1960); T. S. Cantrell and H. Shechter, *ibid.*, **85**, 3300 (1963), and the references therein.

(2) V. D. Azatyan and R. S. Gyuli-Kevkhyan, *Izv. Akad. Nauk Arm. SSR Khim. Nauk*, **14**, 451 (1961), and previous references.

(4) R. M. Fuoss, *J. Am. Chem. Soc.*, **80**, 5059 (1958).

(5) This value has been used by others: *e.g.*, J. L. Dye, G. E. Smith, and R. F. Sankuer, *ibid.*, **82**, 4797 (1960). It was not adjusted in the analysis described here.

(6) C. A. Hutchison, Jr., and R. C. Pastor, *J. Chem. Phys.*, **21**, 7959 (1953).

(7) C. A. Kraus, *J. Am. Chem. Soc.*, **30**, 1192 (1908). The solvent activity was estimated by extended Debye-Hückel theory.

(8) See, for example, C. A. Kraus, *ibid.*, **43**, 749 (1921); E. C. Evers and P. W. Frank, Jr., *J. Chem. Phys.*, **30**, 61 (1959).

(9) G. E. Gibson and T. E. Phipps, *J. Am. Chem. Soc.*, **48**, 312 (1926).

(10) J. V. Acrivos and K. S. Pitzer, *J. Phys. Chem.*, **66**, 1993 (1962); H. M. McConnell and C. H. Holm, *J. Chem. Phys.*, **26**, 1917 (1957).

(11) M. Gold and W. L. Jolly, *Inorg. Chem.*, **1**, 818 (1962).