These resins are the first ones known to show a selectivity for sodium over potassium. This phenomenon and the subsequent inversion of the order of selectivity for the alkali cations as compared to sulfonic resins may be explained by a consideration of the polarizability of ionic groups and water as calculated by Teunissen and Bungenberg de Jong.[4] They found the order of polarizability to be: phosphate > water > sulfate. Since the order of polarizing ability of the alkali cations is Li > Na > K it would be expected that whereas in the sulfonic acid resins the volume sequence, as has been shown by Gregor, Gutoff and Bregman,[5] is Li > Na > K and consequently the order of preference for the alkali cations is K > Na > Li, in the case of the phosphonic resin the volume sequence should be K > Na > Li and the order of selectivity Li > Na > K. These volume and selectivity orders are in accord with values found in this laboratory for these resins and consequently the pressure-volume selectivity theory as expounded by Gregor[6] may be considered to apply to these systems when modified by the Teunissen–Bungenberg de Jong polarizability considerations. A detailed discussion of the experimental data together with the extension of this theory to carboxylic exchange resins will be given in a forthcoming paper.[7]

These resins show a volume increase of about 50% on going from the hydrogen to the sodium state. They are orange-yellow in the hydrogen state but show a striking color change to dark brown when placed in any of the alkali metal states.

Potential applications of phosphonous and phosphonic resins as a result of their unique properties include sodium depletion in physiological applications, rare earth separations, and use in mixed bed and reverse demineralization units.

[4] P. H. Teunissen and H. G. Bungenberg de Jong, *Kolloid Beihefte*, **48**, 80 (1938).

[5] H. P. Gregor, Fradelle Gutoff, and J. I. Bregman, *J. Colloid Science*, **6**, 3, 245 (1951).

[6] H. P. Gregor, THIS JOURNAL, **73**, 642 (1951).

[7] J. I. Bregman, and Y. Murata, in preparation.

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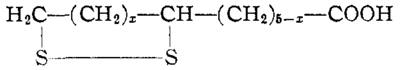
STRUCTURE OF PROTOGEN-A

Sir:

An unidentified growth factor for *Tetrahymena geleii* was first described in 1944 by Kidder and Dewey.[1] Using the test described by these workers it was found that several substances would produce a response in the organism.[2] These factors were called the "protogens."[2,3] The isolation of the sulfur-containing compound protogen-B from liver was described recently.[3] This compound (I) upon titration with sodium hydroxide was found to have a molecular weight corresponding to about 230 on the basis of one carboxyl group per molecule. Elementary analysis indicated the presence of 8 carbon and 2 sulfur atoms. When saponified with an excess of sodium hydroxide, I was converted to another compound (II) which gave a positive nitroprusside reaction and which contained one –SH group as indicated by titration with iodine. Reduction of I with sodium borohydride yielded a third compound (III) which contained two –SH groups as shown by iodine titration. Mild oxidation readily converted III to a disulfide (IV) as indicated by the disappearance of the nitroprusside reaction and by its reappearance on treatment with cyanide. Protogen-A[3] also gave a nitroprusside reaction after treatment with cyanide. A band at 1040 cm.$^{-1}$, present in the infrared absorption spectrum of protogen-B and indicating a sulfoxide group, was absent from the spectra of IV and of protogen-A. Protogen-A and IV appeared to be identical as shown by biological activity, liquid–liquid countercurrent distribution, paper chromatography and infrared absorption spectra. The absence of C-methyl groups in I was indicated by a negative Kuhn–Roth determination. Upon treatment of I with Raney nickel,[4] octanoic acid was obtained and identified by means of its infrared absorption spectrum, its melting point, and the X-ray powder photograph of its S-benzylthiuronium salt. These findings showed the probability of the following structure for IV, I being presumed to be a



$$\underset{\textstyle S\text{—————}}{H_2C}-(CH_2)_x-\underset{\textstyle S}{CH}-(CH_2)_{5-x}-COOH$$

sulfoxide. By the use of molecular models, a stable ring could be constructed for $x = 2$. The name "thioctic acid" is proposed for this structure ($x = 2$), a sulfur-containing organic acid with 8 carbon atoms. The synthesis of DL-thioctic acid with biological activity corresponding to that of the "protogens"[2] and the "lipoic acids"[5] is described in another communication.[6] Numerical prefixes indicating the position of the carbon atom to which the secondary sulfur is attached may be used to designate compounds in this series with different values for x.

[1] G. W. Kidder and V. Dewey, *Biol. Bull.*, **87**, 121 (1944).

[2] E. L. R. Stokstad, *et al.*, *Arch. Biochem.*, **20**, 75 (1949).

[3] E. L. Patterson, *et al.*, THIS JOURNAL, **73**, 5919 (1951).

[4] R. Mozingo, *et al.*, *ibid.*, **65**, 1013 (1943).

[5] L. J. Reed, *et al.*, *Science*, **114**, 93 (1951).

[6] M. W. Bullock, *et al.*, THIS JOURNAL, **74**, 1868 (1952).

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SYNTHESIS OF *DL*-THIOCTIC ACID

Sir:

Thioctic acid,[1] a compound with the biological activity of protogen, was synthesized as follows: furylacrolein was hydrogenated to 2-tetrahydrofurylpropanol (I) over Raney nickel.[2] I was converted to 2-tetrahydrofurylpropyl chloride (II) with thionyl chloride and II was converted to γ-(2-tetrahydrofuryl)-butyric acid (III).[3] III was converted to a mixture of 5-hydroxy-8-iodocaprylic

[1] J. A. Brockman, Jr., *et al.*, THIS JOURNAL, **74**, 1868 (1952).

[2] A. Hintz, *et al.*, *Ber.*, **76**, 676 (1943).

[3] H. Gilman and H. P. Hewlett, *Rec. Trav. Chim.*, **51**, 93 (1932).