The distillation residue was negligible.

Ethyl O-(3-Diethylphosphonopropionyl)-polyhydracrylate (VII).—Triethyl phosphite (16.6 g., 0.1 mole) and β-propiolactone (28.8 g., 0.4 mole) were mixed and cooled in a water-bath while triethylamine (5 ml.) was added dropwise with vigorous stirring. The temperature rose to 40° and remained there for 30 minutes. The water-bath was removed and the reaction mixture was stirred for 4 hours, then allowed to stand overnight. The unreacted starting materials were removed by distilling to a temperature of 65° (3.0 mm.). The product, obtained as residue, was a viscous, light-yellow oil, n^{20}_D 1.4570, having an average molecular weight of 490 (ebulliometric determination in benzene).

Ethyl 4-(Diethylphosphono)-butyrate (V). (Method A).—Triethyl phosphite (66.4 g., 0.4 mole) and γ-butyrolactone (34.4 g., 0.4 mole) were mixed in a rocking autoclave and reacted at 225° for 36 hours. After unreacted starting materials had been removed, 12 g. (12%) of V, b.p. 129–133° (1.8 mm.), n^{20}_D 1.4382, d^{20}_4 1.1069, was obtained.

Anal. Calcd. for $C_{10}H_{21}O_5P$: P, 12.28. Found: P, 12.18, 12.13.

(Method B).—Triethyl phosphite (166 g., 1.0 mole) was treated with ethyl 4-bromobutyrate (195 g., 1.0 mole) in a typical Arbuzov reaction. The product (111.6 g., 44%) was collected at 138–148° (3.2 mm.). Upon redistillation, it boiled at 117–119° (0.4 mm.), n^{20}_D 1.4391, d^{20}_4 1.0860.

Anal. Calcd. for $C_{10}H_{21}O_5P$: C, 47.61; H, 8.39; P, 12.28. Found: C, 47.62; H, 8.18; P, 12.15.

The infrared spectra of samples of V obtained by methods A and B were identical. The following characteristic absorption bands were observed from their spectra

Absorption band, μ	Assignment	Absorption band, μ	Assignment
5.8	C=O (ester)	8.6	P–O–C_2H_5
8.0	P=O	9.7	C–OP
8.5	C–O (ester)	10.4	P–OC

Diethyl 5-(Carbamoylpentyl)-phosphonate (VIII).—Caprolactam (22.6 g., 0.2 mole) and diethyl hydrogen phosphite (55.2 g., 0.4 mole) were mixed and heated at 160° for 8 hours. Fractionation of the reaction mixture gave 31.0 g. of unreacted diethyl hydrogen phosphite, b.p. 51–52° (0.7 mm.), an intermediate cut of 3.5 g., b.p. 53–105° (0.7 mm.), and 12 g. (24%) of product, b.p. 105–108° (0.5–1.0 mm.), n^{20}_D 1.4418, d^{20}_4 1.0608.

Anal. Calcd. for $C_{10}H_{22}NO_4P$: N, 5.57; P, 12.33. Found: N, 5.39; P, 12.83, 12.93.

The distillation residue amounted to 26.6 g. of transparent, amber resinous material which contained 6.86% nitrogen and 11.84% phosphorus. Both VIII and the residue liberated a volatile base when treated with aqueous sodium hydroxide. The following characteristic absorption bands were observed from the infrared spectrum of VIII

Absorption band, μ	Assignment	Absorption band, μ	Assignment
3.05, 3.24	NH_2 (amide)	8.6	P–O–C_2H_5
6.05	C=O (amide)	9.6	C–OP
8.0	P=O	10.25	P–OC

Reaction Product of Caprolactam and Triethyl Phosphite.—Caprolactam (11.3 g., 0.1 mole) and triethyl phosphite (33.2 g., 0.2 mole) were mixed and refluxed for 32 hours at 165–170°. After removing the excess triethyl phosphite, 7.5 g. of distillate boiling at 106–109° (1.6 mm.) was obtained. After standing for a few minutes, 2.0 g. of caprolactam (m.p. 67–68°) crystallized from the distillate, leaving a light-yellow oil, n^{20}_D 1.4790.

Anal. Calcd. for $C_{12}H_{26}NO_4P$: N, 5.02; P, 11.09. Found: N, 7.10; P, 8.58, 8.71.

The product apparently still contained some dissolved caprolactam since the nitrogen and phosphorus analyses obtained were intermediate between the values required for IX and caprolactam. The distillation residue amounted to 9 g. and was a viscous, amber colored, water-soluble liquid which contained both phosphorus and nitrogen. Both the distillate and the residue liberated a volatile base when treated with aqueous sodium hydroxide.

Acknowledgment.—We would like to express our appreciation to Mr. J. H. Chaudet and Mr. Cham Canon for their help in interpreting the infrared data presented.

KINGSPORT, TENN.

[CONTRIBUTION FROM RESEARCH LABORATORIES OF VICTOR CHEMICAL WORKS]

Phenoxymethylphosphonic Acids and Phosphonic Acid Ion-exchange Resins[1]

BY EDWARD N. WALSH, THOMAS M. BECK AND A. D. F. TOY

RECEIVED MARCH 14, 1956

A series of substituted phenoxymethylphosphonic acids has been prepared from the reaction of sodium phenoxides with disodium chloromethylphosphonate. These acids condense with formaldehyde under alkaline conditions to form methylolated phenoxymethylphosphonic acids, analogous to saligenin, and when heated under acidic conditions with excess formaldehyde, form insoluble thermosetting resins which possess ion-exchange properties. Phenoxymethylphosphonic acid resins behave as dibasic acids having equivalence points at *p*H 5.0 and *p*H 10.2. The preference of the resin for ions was determined.

Introduction

A series of substituted phenoxymethylphosphonic acids[2] was prepared, originally for evaluation as herbicides. The method of preparation, analogous to that of aryloxyacetic acids[3] except for the higher temperatures required, is shown in equation 1.

$$C_6H_5ONa + ClCH_2PO_3Na_2 \xrightarrow{2\ HCl} C_6H_5OCH_2PO_3H_2 + 3NaCl + H_2O \quad (1)$$

These new compounds are listed in Table I.

In the course of this investigation phenoxymethylphosphonic acid was found to condense with formaldehyde in a reaction similar to the condensation of phenol with formaldehyde[4] to form resinous products. When disodium phenoxymethylphosphonate is refluxed with an excess of aqueous formaldehyde, a saligenin type compound is formed in accord with equation 2, which will not

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(1) Presented before the Division of Organic Chemistry, 127th National Meeting, American Chemical Society, Cincinnati, Ohio, March 29 to April 7, 1955.

(2) The preparation of sodium alkyl 2,4-dichlorophenoxymethylphosphonates by a method similar to ours was recently reported by Maguire, *et al.*: M. H. Maguire, G. Shaw and C. G. Greenham, *Chemistry and Industry*, **27**, 668 (1953); M. H. Maguire and G. Shaw, *J. Chem. Soc.*, 1756 (1955); G. Greenham, *Australian J. Sci.*, **16**, 66 (1953).

(3) W. Heintz, *Ann. Physik*, **109**, 489 (1860); *Jahresber. Fort. Chem.*, 361 (1859).

(4) L. Lederer, *J. prakt. Chem.*, **50**, 224 (1894); O. Manasse, *Ber.*, **27**, 2408 (1894).

TABLE I

PHENOXYMETHYLPHOSPHONIC ACIDS ($ROCH_2PO_3H_2$)

R	Yield, g.	M.p., °C.	Analyses Phosphorus Calcd.	Analyses Phosphorus Found	Analyses Chlorine Calcd.	Analyses Chlorine Found	Mol. wt. Calcd.	Mol. wt. Found
C_6H_5-	65.4	141–142	16.5	16.5	..	..	188	188
$2\text{-}CH_3C_6H_4-$	73.5	157–158	..	..	..	..	202	204
$3\text{-}CH_3C_6H_4-$	80.2	115–117	..	..	0.0	0.0	202	202
$4\text{-}(CH_3)_3CC_6H_4-$	68.0	132–134	12.7	12.6	.0	.0	244	244
$4\text{-}BrC_6H_4-$[a]	84.0	166–168	11.6	11.5	.0	.0	267	267
$4\text{-}ClC_6H_4-$	76.2	156–157	13.9	14.1	15.9	15.9	222.5	222
$2,4\text{-}Cl_2C_6H_3-$	73.7	141–142	12.1	12.5	27.6	27.0	257	257
$2,4,5\text{-}Cl_3C_6H_2-$	89.9	175–178	10.6	10.8	36.6	36.2	291.5	291

[a] *Anal.* Calcd. for $C_7H_8O_4BrP$: Br, 29.9. Found: Br, 29.6.

resinify when heated. This salt, when acidified in an excess of formaldehyde, is converted to a resinous material which, upon further heating at 140°,

$$C_6H_5OCH_2PO_3Na_2 + CH_2O \longrightarrow HOCH_2C_6H_4OCH_2PO_3Na_2 \quad (2)$$

is condensed to an insoluble, thermosetting resin, having ion-exchange properties. Such a thermosetting resin may also be obtained by the direct condensation of phenoxymethylphosphonic acid with an excess of formaldehyde. The resin obtained in this manner is highly cross-linked and has both strong and weak acid groups. Similar cross-linked resins were obtained when substituted phenoxymethylphosphonic acids, having both the *ortho* and *para* positions of the phenoxy group available for reaction, were treated with an excess of formaldehyde. When one of these positions is blocked, as in the case of *p*-chlorophenoxymethylphosphonic acid, only fusible, water-soluble resins are obtained.

The titration curves for two cross-linked resins are shown in Fig. 1. These curves indicate that the resin behaves as a dihydrogen acid, with equivalence points similar to the phosphonic acid exchange resin of undisclosed composition reported by Bregman and Murata.[5] Quantitatively, however, the phenoxymethylphosphonic acid resins have higher exchange capacities at all *p*H values. The titration curves indicate that the *pK* values of the acid groups of the phenoxymethylphosphonic acid resins are similar to the *pK* values obtained for organophosphonic acids.[6]

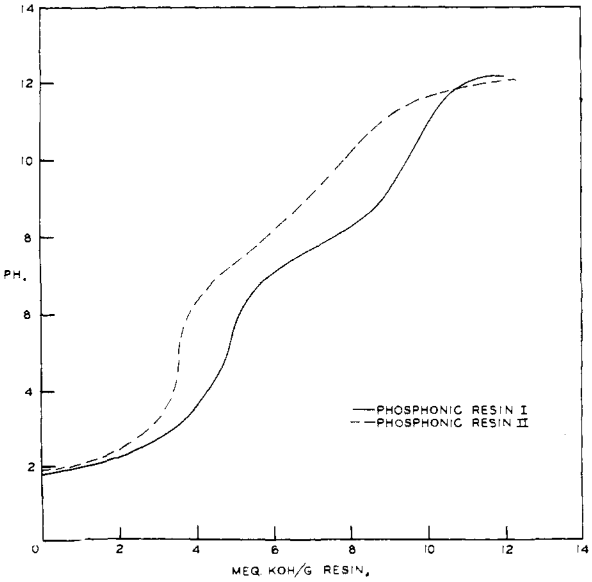

Fig. 1.—Titration of ion-exchange resins in 1 *M* KCl.

The exchange properties of the resins are illustrated in Table II. The preference of the resins for ions is

$$H^+ > Ca^{++} > Cu(NH_3)_4{}^{++} > Mg^{++} > Cu^{++} > NH_4{}^+ > Na$$

Acid regeneration is most effective, proceeding in over 90% efficiency, whereas the efficiency of salt regeneration is seldom over 5%.

Cuprammonium ion behaves anomalously, with more than 100% of the calculated exchange occurring before the break-through point, and the saturation point of the resin being 206% of the calculated capacity. After the break-through point this abnormal adsorption is accompanied by a precipitate within the resin bed, which may account for the unusual amount of copper removal.

TABLE II

ION EXCHANGE REACTIONS OF RESIN I

Ionic form of resin	Influent	Break-through point, % exchange	Regeneration	
			Regenerant	Regeneration, %
H	0.1 *N* NaOH[a]	91	0.1 *N* HCl	95
Na	.005 *N* $Ca(NO_3)_2$	85	0.1 *N* HCl	90
			2 *N* NaCl	5
H	.50 *N* $Ca(NO_3)_2$	27	0.1 *N* HCl	95
Na	.10 *N* $CuSO_4$	41	2 *N* NaCl	1
NH_4	.10 *N* $Cu(NH_3)_4SO_4$	106	1 *N* NH_4Cl	41
Na	.10 *N* $MgSO_4$	40	0.1 *N* HCl	38
			2 *N* NaCl	5

[a] A volume increase of approximately 100% occurs when the resin is converted to the sodium form.

Acknowledgment.—The authors are indebted to the assistance of Messrs. A. R. Wreath and D. Bernhart, who carried out the analytical tests reported in this paper.

Experimental

Materials.—Chloromethylphosphonic acid was prepared as previously described.[7] Monosodium chloromethylphosphonate was prepared by neutralizing an aqueous

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(5) J. I. Bregman and Y. Murata, THIS JOURNAL, **74**, 1867 (1952).

(6) P. Rumpf and V. Chavanne, *Compt. rend.*, **224**, 919 (1947); L. D. Freedman and G. O. Doak, THIS JOURNAL, **75**, 2209 (1953); G. M. Kosolapoff, *ibid.*, **75**, 5738 (1953); E. C. Ashby and G. M. Kosolapoff, *ibid.*, **75**, 4903 (1953); P. C. Crofts and G. M. Kosolapoff, *ibid.*, **75**, 3379 (1953).

(7) M. I. Kabachnik and E. S. Shepeleva, *Doklady Akad. Nauk S.S.S.R.*, **75**, 219 (1950).

solution of chloromethylphosphonic acid with one equivalent of sodium hydroxide. The product may be isolated by air drying at 100° and was a white solid.

Anal. Calcd. for CH_3O_3ClNaP: P, 20.3; Cl, 23.3; Cl (ionic), 0.0. Found: P, 20.3; Cl, 23.3; Cl (ionic), 0.0.

Disodium chloromethylphosphonate was prepared by neutralizing an aqueous or alcoholic solution of chloromethylphosphonic acid with two equivalents of sodium hydroxide, and drying the salt under reduced pressure at below 50°; yield 98%.

Anal. Calcd. for $CH_2O_3ClNa_2P$: P, 17.8; Cl, 20.3; Cl (ionic), 0.0. Found: P, 17.4; Cl, 19.8; Cl (ionic), 0.0.

The product was a white, hygroscopic solid. When heated at higher temperatures, the chlorine–carbon bond is cleaved.

The phenols and the formaldehyde were commercial reagents.

Aryloxymethylphosphonic Acids.—The following is a general procedure for making this series of substituted aryloxymethylphosphonic acids. To a mixture of a sodium aryloxide in a phenol, prepared by heating 16.0 g. (0.4 mole) of sodium hydroxide with 200 g. of the corresponding substituted phenol, was added 69.8 g. (0.4 mole) of disodium chloromethylphosphonate. The reaction mixture was stirred for five hours while being heated in an oil-bath held at 160°. The reaction temperature varied from 140–150°. The mixture was cooled and the excess phenol and unreacted sodium aryloxide were extracted with 300 ml. of ethanol. The residual disodium aryloxymethylphosphonate was acidified with 200 ml. of concentrated hydrochloric acid, and the aryloxymethylphosphonic acid was extracted with ether. The ether solution was concentrated on a steam-bath to yield the free acid as a crystalline solid. In Table I are listed the data from the preparations of eight of these compounds.

A more convenient method for preparing phenoxymethylphosphonic acid entailed adding 52.2 g. (0.4 mole) of chloromethylphosphonic acid to the reaction product of 50 g. of sodium hydroxide with 200 g. of phenol in 150 ml. of xylene. The reaction mixture was heated at reflux (145°) five hours. On cooling, 200 ml. of water was added and the mixture was neutralized with hydrochloric acid until the aqueous phase was just acidic to phenolphthalein. The aqueous layer was decanted and extracted twice with 200 ml. of benzene to remove the unreacted phenol. The solution was acidified with 200 ml. of concentrated hydrochloric acid. and the product, which in part precipitated as a dark oil, was extracted with 200 ml. of ether. The ether solution was concentrated on a steam-bath and air dried at 110° to yield 66.0 g. of crystalline phenoxymethylphosphonic acid; m.p., 138–140°; after recrystallization from ether and benzene, m.p. 140–142°.

Alternate methods of preparation for making phenoxymethylphosphonic acid have been tried. These methods include the heating of an aqueous solution of disodium chloromethylphosphonate with sodium phenolate; the heating of aqueous solutions of these reagents in the presence of tertiary amines; and the refluxing of dibutylchloromethylphosphonate in the presence of molar amounts of phenol and diethylaniline. None of these methods led to the desired product.

Aryloxymethylphosphonic acids are dibasic acids, soluble in water, ether and alcohol; they are sparingly soluble in benzene and hexane. When phenoxymethylphosphonic acid is heated with phosphorus pentachloride, phenoxymethylphosphonic dichloride is formed in 20% yield; b.p. 120–130° at 2 mm.; $n^{25}D$ 1.5470.

Anal. Calcd. for $C_7H_7O_2Cl_2P$: P, 13.7; Cl, 31.6. Found: P, 14.0; Cl, 31.4.

The acid chloride, upon hydrolysis, reverts to phenoxymethylphosphonic acid.

Condensation of Phenoxymethylphosphonic Acid with Formaldehyde. Acidic Condensation.—A solution of 10.0 g. of phenoxymethylphosphonic acid in 20.0 ml. of water was refluxed 20 minutes with 6.0 ml. of 37% formaldehyde solution. The excess water was removed by heating the solution until the liquid temperature rose to 110°. The residue, a viscous gum, was treated with 1.0 ml. of formaldehyde solution and baked 16 hours at 140°. A hard, brittle, insoluble solid was obtained; yield 11.0 g.

Anal. Calcd. for $(C_{17}H_{18}O_8P_2)_n$: P, 15.0. Found: P, 15.0.

The baking time of the gummy condensation product of phenoxymethylphosphonic acid and formaldehyde at 140° has been varied from 3 to 24 hours. When the heating period is three hours or less, a fusible, water-soluble resin is obtained; whereas when the baking period is extended beyond four hours, solid, infusible, insoluble resins are produced.

The residue was ground and screened to obtain a fraction which passed through a 20 mesh screen and did not pass through a 60 mesh screen. Particles finer than 60 mesh were recycled in subsequent preparations. This fraction of resin was washed with 2 *N* sodium hydroxide, water and hydrochloric acid. The solution was dried at 110°. The phosphorus content was unchanged by this treatment.

One gram of this resin was treated with excess 0.1 *N* sodium hydroxide, and the unreacted alkali was titrated. A total of 9.66 meq. of sodium ion was exchanged.

Alkaline Condensation.—A solution of 4.64 g. of disodium phenoxymethylphosphonate in 20 ml. of water and 5.0 g. of 37% formaldehyde was refluxed for one hour. The excess water and formaldehyde were removed on a steam-bath. A white solid residue of disodium methylolphenoxymethylphosphonate was obtained; yield 5.2 g. (98%).

Anal. Calcd. for $C_8H_9O_5Na_2P$: P, 11.8; equiv. wt., 262. Found: P, 11.8; equiv. wt., 260.

This compound did not resinify when heated to 160°.

A solution of 4.64 g. of disodium phenoxymethylphosphonate in 20 ml. of water and 5.0 g. of 37% formaldehyde solution was heated at reflux for one hour. The solution was cooled, acidified with 10 ml. of concentrated hydrochloric acid and extracted with ether. The ether solution was concentrated to yield a viscous, gummy oil; yield 4.5 g. The phosphorus content, 11.8, indicates an average of more than two methylol groups are condensed for each phenoxy group.

Baking this oil overnight at 140° yielded 4.0 g. of a hard, brittle resin with ion-exchange properties. The phosphorus content of this product was 14.9, the same as for the previously described resin.

Condensation of 3-Methylphenoxymethylphosphonic Acid with Formaldehyde.—A solution of 30.3 g. of 3-methylphenoxymethylphosphonic acid in 100 ml. of water and 150 ml. of 37% formaldehyde solution was heated two hours at reflux. The solution was concentrated to a viscous sirup by heating until a liquid temperature of 115° was reached. The residue thus obtained was baked for 16 hours at 150°. A hard, brittle resin was obtained; yield 33.0 g. (92%). The product was crushed and screened.

Anal. Calcd. for $(C_{19}H_{22}O_8P_2)_n$: P, 14.0; Cl, 0.0. Found: P, 13.3; Cl, 0.2.

The exchange capacity of the resin passing through a 20 mesh screen and not passing through a 60 mesh screen was found to be 8.6 meq. per g.

Condensation of 4-Chlorophenoxymethylphosphonic Acid with Formaldehyde.—A solution of 10.0 g. of 4-chlorophenoxymethylphosphonic acid in 20 ml. of water and 6.0 ml. of 37% formaldehyde solution was refluxed four hours. The resultant solution was concentrated by heating until the liquid temperature was 110°. The residue, a tacky material, was baked 16 hours at 140°. The product was a fusible resin, soluble in cold water.

Condensation of Phenoxymethylphosphonic Acid with Phenol and Formaldehyde.—A solution of 20.0 g. of phenol and 5.0 g. of phenoxymethylphosphonic acid dissolved in 210 g. of 10.6% formaldehyde solution was refluxed seven hours. A white solid separated which was removed by filtration and was baked at 140° for 16 hours. The amber solid thus obtained had ion-exchange properties.

Anal. Found: P, 3.2.

This indicates a condensate containing 21% phenoxymethylphosphonic acid.

Condensation of Phenoxymethylphosphonic Acid with Melamine and Formaldehyde.—A solution of 18.8 g. of phenoxymethylphosphonic acid in 50 ml. of water was treated with 10.0 g. of paraformaldehyde and the reaction mixture was refluxed for two hours. A clear solution was obtained which was cooled to 25° and was neutralized with ammonium hydroxide to a *p*H of 7.0. A solution of 15.0 g. of trimethylol melamine (Resloom HP) in 50 ml. of water was added, and the resulting solution was refluxed for one hour. This solution, if allowed to stand, precipitates out a solid resin containing phosphonic acid groups. When the solution is padded on cloth and the impregnated cloth is heated for ten minutes at 140° an insoluble, cross-linked resin condenses, which imparts flame resistance to the material. That the cloth behaves as an ion exchanger is evidenced by the following. When the cloth is treated with sodium salts, the sodium is adsorbed and the cloth loses its flame resistance. On treating the cloth with ammonium salts the flame resistance of the cloth is restored. Similarly, the flame resistance can be restored if dilute acids are used to generate the acid form of the ion exchanger.

Ion-exchange Reactions.—The titration curves of the exchange resins obtained from the condensation of formaldehyde with phenoxymethylphosphonic acid (I) and with 3-methylphenoxymethylphosphonic acid (II) are illustrated in Fig. 1. These resins behave as dibasic acids having equivalence points at *p*H values of 5.0 and 10.2.

A 2-inch column containing 24.2 g. of the acid form of I, and having a total exchange capacity of 232 milliequivalents, was tested for ion-exchange properties by passing solutions of known concentration through the column until both the break-through point (1% leakage) and the saturation point of the resin had been reached. The resin was regenerated with the theoretical amount of regenerant. Typical data are tabulated in Table II. Except for having a slightly lower exchange capacity, the ion-exchange properties of II were similar to those reported for I.

CHICAGO HEIGHTS, ILLINOIS

[CONTRIBUTION FROM THE NOYES CHEMICAL LABORATORY, UNIVERSITY OF ILLINOIS]

The Structures of Grantianine and Sceleratine. A Suggested Biogenesis of the Acids in the Alkaloids from Senecio and Crotalaria Species

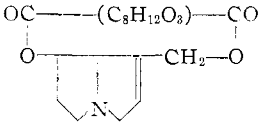
BY ROGER ADAMS AND MAURIZIO GIANTURCO

RECEIVED FEBRUARY 9, 1956

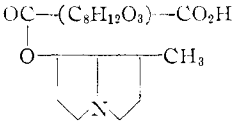
Grantianine, the alkaloid from *Crotalaria grantiana*, has been reinvestigated. Grantianic acid, which is esterified with retronecine to form the alkaloid, has been shown to be an oxidation product of trichodesmic acid. A reinterpretation of de Waal's experiments on sceleranecic acid dilactone has resulted in the postulation of a new formula for it, which conforms to those of the acid moieties of other Crotalaria alkaloids. A structure for the alkaloid sceleratine is proposed. The possible existence of a common biogenetic pathway to the formation of the various acids, which when esterified with retronecine and related bases, provide the large class of pyrrolizidine alkaloids is discussed.

The alkaline hydrolysis of the alkaloid grantianine, $C_{18}H_{23}NO_7$, extracted from *Crotalaria grantiana*, gave retronecine and an acid which could not be isolated in a pure state.[1] Upon hydrogenation over a platinum catalyst, grantianine absorbed two moles of hydrogen and formed tetrahydrograntianine, $C_{18}H_{27}NO_7$.

At the time of these earlier experiments the structure of retronecine had not been elucidated. With this structure now known,[2] the condensed formulas for grantianine and tetrahydrograntianine may be written as I and II, respectively.



I



II

The infrared spectrum has now revealed that the alkaloid contains two ester carbonyl groups absorbing at 1717 and 1732 cm.$^{-1}$, a γ-lactone absorbing at 1765 cm.$^{-1}$, and an alcoholic hydroxyl group absorbing at 3520 cm.$^{-1}$. In the infrared spectrum of tetrahydrograntianine are found bands for an alcoholic hydroxyl group, a γ-lactone, an unconjugated ester, an acid (zwitterion) and a salt structure as evidenced by bands at 3380, 1767, 1736, 1615 and 2200–2400 cm.$^{-1}$, respectively.

In the introductory paper,[1] a small amount of by-product was reported with the tetrahydrograntianine after the reduction of the alkaloid. It was isolated only as a picrate, $C_{18}H_{27}NO_6 \cdot C_6H_3N_3O_7$ or $C_{18}H_{25}NO_6 \cdot C_6H_3N_3O_7$. The alkaloidal moiety has one less oxygen or one less molecule of water than tetrahydrograntianine and the infrared spectrum of the picrate shows the absence of the γ-lactone band. This by-product was probably due to the presence of an impurity of lower oxygen content in the grantianine, since the reduction of a chromatographically-pure sample of alkaloid afforded a single product as indicated by a chromatogram. Moreover, by changing slightly the isolation procedure previously described, practically a quantitative yield of tetrahydrograntianine resulted.

The possibility that the by-product picrate, $C_{18}H_{27}NO_6 \cdot C_6H_3N_3O_7$ or $C_{18}H_{25}NO_6 \cdot C_6H_3N_3O_7$, was formed by an acid-catalyzed reaction of the main product of hydrogenation, $C_{18}H_{27}NO_7$, followed by picrate formation was excluded when treatment of pure tetrahydrograntianine with aqueous picric acid yielded a characteristic picrate, $C_{18}H_{27}NO_7 \cdot C_6H_3N_3O_7$, whose infrared spectrum still showed γ-lactone, ester carbonyl and acid carbonyl bands at 1770, 1740 and 1710 cm.$^{-1}$ (shoulder), respectively, and a band for an alcoholic hydroxyl at 3420 cm.$^{-1}$.

The physical properties of pure grantianine and tetrahydrograntianine, as previously determined, were confirmed in this investigation. Since grantianine is a Crotalaria alkaloid and contains the same number of carbon atoms as trichodesmine (III),[3] it is likely to be closely related in structure to the latter. A structure that fulfills all the requirements is shown in IV. Tetrahydrograntianine would then have structure V.[4]

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(1) R. Adams, M. Carmack and E. F. Rogers, THIS JOURNAL, **64**, 571 (1942).

(2) R. Adams and N. J. Leonard, *ibid.*, **66**, 257 (1944).

(3) R. Adams and M. Gianturco, *ibid.*, **78**, 1922 (1956).

(4) A convenient microtest for determining whether by reduction of the alkaloid an intramolecular salt or an ordinary salt is formed is given in the Experimental part. Treatment of an aqueous solution with Dowex 50 in the hydrogen phase causes no change in the *p*H in the former but a change toward more acidic values in the latter.