a previously heated mixture of 4-methyl-1-pentanol (4.4 g) and NaNH₂ (2.1 g) in PhMe (10 ml). The reaction was carried out as for Vc and afforded a white solid (2.45 g), mp 85–88°. Recrystallization from hexane gave pure Vd: mp 97–99°; $\nu_{\rm max}$ 1115 cm⁻¹ (COC); nmr peaks at 0.94 [doublet, J = 6 cps, C(CH₃)₂] and 4.15 ppm (triplet, J = 6.5 cps, OCH₂). Anal. (C₁₅H₁₈INO) C, H.

4-Dimethylamino-7-iodoquinoline (Ve).--Me₂NH was bubbled through an ice-cooled solution of IVb (2 g) in PhMe (20 ml) and MeCOEt (10 ml) for 3 hr in a pressure bottle. The bottle was tightly stoppered and placed in an oven at 50° for 10 days. The mixture was cooled and washed (H₂O). The organic phase was dried (Na₂SO₄) and the solvent was removed *in racuo*. Recrystalization of the solid residue gave pure Ve (1.1 g), mp 107-108°, and an nmr peak at 2.99 ppm (NCH-). Anal. (C₁₁H₁₁IN₂) C, H.

4-Hydroxyethyoxy-7-iodoquinoline (Vf).--A solution of Ve (100 mg) in ethylene glycol (1.5 ml) was heated in an oil bath at 185° for 16 hr, cooled, and diluted with H₂O. The precipitate (70 mg), mp 153–155°, was recrystallized (Me₂CO-H₂O) to give pure Vf, mp 154–155°. The ir and nmr spectra were as expected. *Anal.* (C₁₁H₁₀INO₂) C, H.

Isotope Exchange. General Method.— A solution containing 1-3 mCi of Na¹²⁵I was placed in a 10-ml round-bottom flask and evaporated to dryness at 100° under a gentle stream of N₂. The

substituted 7-iodoquinoline (100 mg) dissolved in the appropriate solvent (2 ml) was added, a condenser was attached, and the bath temperature was raised. The mixture was stirred under N₂ for the specified time and allowed to cool. In the case of IVa, Va, and Vc, H₂O was added and the product was collected by filtration and washed well (H₂O). For Vb, the solution was concentrated to approximately 0.5 ml under reduced pressure and treated with H₂O and NH₄OH, and the precipitate was collected as above. For Vd, the solvent was removed *in vacuo*, the residue was treated with H₂O containing a little Me₂CO, and the precipitate was collected. In all cases, the products were purified by recrystallization and the purity was established by (a) the and a radiochromatogram of the strip and (b) mixture melting point with authentic samples (see Table III).

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S-2-(ω-Aminoalkylamino)ethyl Dihydrogen Phosphorothioates and Related Compounds as Potential Antiradiation Agents¹

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A number of S-2-(ω -aminoalkylamino)ethyl and S-3-(ω -aminoalkylamino)propyl dihydrogen phosphorothioates (3a-e, 18a-c) and some related compounds including the S-2-(ω -aminoalkylamino)ethyl hydrogen thiosulfates 10a-c have been prepared and evaluated for radioprotective activity in mice. Intermediate N-(2-bromoethyl)- α , ω -alkanediamine dihydrobromides (2a-e) were prepared by the Cortese treatment of the 2-(ω -aminoalkylamino)ethanols 1a-e; the potential of a Gabriel synthesis from the 3-(ω -phthalimidoalkyl)-2-oxazolidinones 7a-c was demonstrated by the conversion of N-[3-(2-bromoethylamino)propyl]phthalimide hydrobromide (8b) into 2b. The requisite N-(3-bromopropyl)- α , ω -alkanediamine dihydrobromides 17a-c were prepared from the 3-(ω -aminoalkylamino)-1-propanols 16a and 16b and from the 3-(ω -phthalimidoalkyl)tetrahydro-1,3-oxazin-2ones 14a and 14b in two steps involving selective cleavage of the tetrahydrooxazinone ring. Intermediates obtained by the addition of 2-methyl- and 2,2-dimethylaziridine to acrylonitrile led to several branched-chain analogs (21a-d, 23a, and 23b). Aziridine-ring opening by ammonium thiosulfate was employed in the preparation of the inner Bunte salts 10a, 10b, 21b, and 21d monohydrochlorides. The phosphorothioates, as a series of a novel type, exhibited an exceptionally high level of radioprotective activity, whereas the thiosulfates were essentially nonprotective.

Current interest in the radioprotective properties of N-substituted derivatives of 2-aminoethanethiol (with and without latentiating S-substitution) in which the N-substituent is a terminally and functionally substituted alkyl group is attested by a growing number of reported syntheses in this area.² This report concerns the synthesis and evaluation of N-(ω -aminoalkyl)-substituted derivatives (chiefly N and S disubstituted), a type that structurally resembles several recently described and more complex spermine and spermidine derivatives³ and N,N'-polymethylenebridged derivatives⁴ in which some antiradiation activity has been observed.

Various modifications of 2-aminoethanethiol have been achieved by the use of α -amino acids as starting materials,⁵ but the general reaction sequence was not successfully applied to L-lysine or its ethyl ester because of difficulties encountered in their reduction to the apparently as yet unknown L-lysinol [H₂N-(CH₂)₄CH(NH₂)CH₂OH]. As a model for the planned conversion of L-lysinol the following sequence (eq. 1)

$$\begin{array}{c} \mathrm{H}_{2}\mathrm{NCH}_{2}\mathrm{CH}_{2}\mathrm{NHCH}_{2}\mathrm{CH}_{2}\mathrm{OH} \xrightarrow{\mathrm{HBr}} \\ \mathbf{1a} \\ \mathrm{H}_{2}\mathrm{NCH}_{2}\mathrm{CH}_{2}\mathrm{NHCH}_{2}\mathrm{CH}_{2}\mathrm{Br} \cdot \mathrm{HBr} \xrightarrow{\mathrm{Na}_{3}\mathrm{SPO}_{3}} \\ \mathbf{2a} \\ \mathrm{H}_{2}\mathrm{NCH}_{2}\mathrm{CH}_{2}\mathrm{NHCH}_{2}\mathrm{CH}_{2}\mathrm{SPO}_{3}\mathrm{H}_{2} \quad (1) \\ \mathbf{3a} \end{array}$$

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beginning with commercially available 2-(2-aminoethylamino)ethanol (1a) was carried out. The product 3a was a unique example of a phosphorothioic acid ester in which the acidic function can be neutralized internally by two amino groups. Whether the internal zwitterionic neutralization is partial or complete as in $H_3NCH_2CH_2CH_2CH_2CH_2SPO_3^{2-}$ in the solid state or in solution is not known, but for convenience phosphorothioate structures in this paper are written in the nonzwitterionic form. The radioprotective activity of 3a in initial screening tests encouraged the preparation of the homologous and also impressively active S-2-(3-aminopropylamino)ethyl dihydrogen phosphorothioate (3b) by the following route (eq 2) based

on known aziridine intermediates.⁶ These beginnings, marked by a high level of activity, were then expanded into a series of homologs and analogs.

The two routes that led to the S-2-(ω -aminoalkylamino)ethyl dihydrogen phosphorothioates **3** are outlined in Scheme I; one involved the Cortese conversion⁷ of hydroxyethylated α , ω -alkanediamines, and the other involved the Gabriel synthesis from intermediates made available by the recently developed hydrogen bromide cleavage of 3-substituted 2-oxazolidinones.⁸ The last step of each approach was based on methods developed by Åkerfeldt,⁹ but the favorable stoichiometry¹⁰ of this particular application permitted the isolation of inner salts without additional acid (eq 3).

$$2 + \operatorname{Na}_{3} \operatorname{PSO}_{3} \xrightarrow{\operatorname{H}_{2} \operatorname{O}} 3 + 3 \operatorname{NaBr}$$
(3)

The stoichiometry of the conversion of the N-(2bromoethyl)- α,ω -alkanediamine hydrobromides 2 into the corresponding inner Bunte salts requires that the reagent Na₂S₂O₃ be protected against acidity.¹⁰ Buffering with NaOAc was effective in the analogous preparation of a Bunte salt from 2-(bromomethyl)piperazine dihydrobromide, but neutralization did not occur and the product was isolated as a hydrobromide.¹¹ In the attempted conversion of 2 in the presence of NaOAc, however, only one member of the series, S-2-(6-aminohexylamino)ethyl hydrogen thiosulfate (10c), could be obtained in crystalline form; the others were obtained as solvated syrups, from which NaBr and NaOAc could not be separated. Two members of the series, 10a and 10b, were ultimately obtained, as indicated in Scheme II, by aziridine-ring openings with $(NH_4)_2S_2O_3$; other examples of the application of this method have been reported.¹²

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The feasibility of a synthetic route to the S-3-(ω aminoalkylamino)propyl dihydrogen phosphorothioates 18 based on the hydrogen bromide cleavage of the 3-substituted tetrahydro-2H-1,3-oxazin-2-ones 14 (Scheme III) was initially demonstrated by the conversion of tetrahydro-2H-1,3-oxazin-2-one (11) itself into S-3-aminopropyl dihydrogen phosphorothioate (13) via 3-bromopropylamine hydrobromide (12). The cleavage of 11 was extremely slow at room temperature, but increased markedly with warming as evidenced by an accelerated evolution of CO_2 . The preparation of the intermediate 14b by the addition of a solution of N-(4-bromobutyl)phthalimide (**5b**) and 11 in DMF to a stirred slurry of NaH in the same solvent exemplified a technical refinement in this type of alkylation. The alternative route to 18a and c provided by the Cortese treatment of the 3-(ω -aminoalkylamino)-1-propanols 16 and shown in Scheme III was developed because of difficulties encountered in the route involving phthalimido intermediates: (1) dehydrobromination occurred in the attempted alkylation of 11 with N-(2-bromoethyl)phthalimide to give N-vinylphthalimide instead of the expected 3substituted tetrahydro-2H-1,3-oxazin-2-one, and (2) analyses of the phosphorothioate 18c derived by the longer route were inconsistent. It should be pointed out that the phthalimido intermediates 8 and 15 were the source of a number of terminal phthalimido analogs, which will be described in a subsequent paper.

Several branched-chain congeners of the title compounds were synthesized by routes outlined in Scheme IV and based on the addition of 2-methylaziridine and 2.2-dimethylaziridine to acrylonitrile. The formation of 2-methyl-1-aziridinepropionitrile (**19a**) and 2,2-dimethyl-1-aziridinepropionitrile (**19b**) was promoted by heat, which was not required in the reported addition⁶ of ethylenimine itself to acrylonitrile. The thiols (isolated as hydrochlorides) and thiosulfates were produced by appropriate aziridine-ring openings, but the product of the ring opening of **19a** with H₂S was not obtained in characterizable form.

The radioprotective activities of the phosphorothioates described above as judged by screening tests performed in mice at the Walter Reed Army Institute of Research, Washington, D. C., are expressed in Table I as per cent survival along with those of several of the corresponding Bunte salts among other compounds. The phosphorothioates, with the exception of **18c** (and **13**), showed good activity (50–100% survival), whereas the corresponding thiosulfates were nonprotective with the exception of the slightly protective



SCHEME III

branched-chain analog 21d. The striking difference between the phosphorothioates and thiosulfates in this series is somewhat surprising in view of the reported good activity of both types of thioester when the substituent is simply a 2-aminoethyl group.¹³ One of the outstanding phosphorothioates in this series, 18b, is a structural relative of S-3-aminopropyl dihydrogen phosphorothioate (13), which, however, showed only slight activity. In fact, the structural requirements for the high level of radioprotective activity observed among the S- ω -(ω -aminoalkylamino)alkyl dihydrogen phosphorothioates examined here, including the branched-chain analogs 23a and 23b, appear to be unusually broad, even for a series of closely related compounds. The effect of substitution on terminal amino groups in this series will be explored in later papers.

Experimental Section¹⁴

2-(ω -Aminoalkylamino)ethanols (1a-e).—Compounds 1a and 1b were obtained from commercial sources; 1c-e were prepared from the corresponding α , ω -alkanediamines and ethylene oxide by an adaptation of the procedure of Steck, et al.¹⁵ In each example the monohydroxyethylated product was isolated by fractional distillation in vacuo; results listed below refer to redistilled products. The yield of 1c, bp 97-100° (0.10 mm) and n^{25} D 1.4800, was 25%; 1d, bp 107-110° (0.10 mm) and n^{25} D 1.4806, 26%; and 1e, bp 118-120° (0.15 mm) (partially solidified after second distillation), 30%. Anal. (C₆H₁₆N₂O, 1c) C, H, N. (C₇H₁₅N₂O, 1d) C, H, N. Although 1e was not obtained analytically pure, it was converted into pure 2e.

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3-(2-Aminoethylamino)-1-propanol (16a).—The procedure that follows is essentially that of Ishiguro and Matsumura.¹⁶ A solution of ethylenediamine (26.4 g, 0.440 mole) and trimethylene oxide (25.0 g, 0.431 mole) in H₂O (20 ml) was heated in a glass-lined pressure vessel at 130–140° for 20 hr. The mixture was fractionated *in vacuo*, and the fraction with bp 130–136° (14 mm) (16.3 g) was redistilled to give **16a** as a colorless hygroscopic oil, bp 136–140° (14 mm), 25% yield (12.8 g) [lit.¹⁶ bp 146–149° (14 mm)]. *Anal.* (C₅H₁₄N₂O) C, H; N: calcd, 23.70; found, 22.90.

3-(4-Aminobutylamino)-1-propanol (16b).—Adaptation of the procedure described for the preparation of 16a led to 16b, bp 128-130° (2 mm), in 29% yield. Anal. (C₇H₁₈N₂O) H; C: calcd, 57.51; found, 58.16.

 $3-(\omega$ -Phthalimidoalkyl)-2-oxazolidinones (7a-c).—Compounds 7b and 7c were each prepared by two methods represented below by typical examples designated methods A and B; 7a was prepared by method A only.

Method A. 7a.—A mixture of equimolar amounts of 4a and potassium phthalimide (66.9 mmoles each) in DMF (10 ml) was stirred at 95–100° (bath temperature) for 2 hr, diluted (H₂O, 70 ml), and refrigerated overnight to give pure 7a, mp 158°, in 94% yield (16.4 g). Anal. ($C_{13}H_{12}N_2O_4$) C, H, N.

7b.—Similar treatment of **4b** gave crude **7b** (93% yield); one recrystallization from EtOAc gave an 80% yield of **7b**, mp 101–103°, suitable for use in preparation of **8b**. An analytical sample of **7b** had mp 105–106° (from EtOAc). Anal. ($C_{14}H_{14}N_{2}O_{4}$) C, H, N.

7c.—The crude product (90% yield) was recrystallized from H_2O to give pure 7c, mp 101–103°, in 67% yield. Anal. (C₁₅- $H_{16}N_2O_4$) C, H, N.

Method B. 7b.—A solution of equimolar amounts of 5a and 6 (81.1 mmoles each) in DMF (150 ml) was added dropwise during 30 min to a stirred mixture of NaH (3.24 g of 60% NaH in oil dispersion, 81.1 mmoles) in DMF (50 ml) maintained at 25°. The resultant mixture was stirred at 25–30° for 18 hr. Removal of the solvent by distillation *in vacuo* (aspirator, bath temperature 70–80°) left a solid residue, which, when stirred with H₂O (200 ml), afforded crude 7b (76% yield). Recrystallization from EtOAc gave pure 7b (melting point and mixture melting point identical with that of the analytical sample prepared by method A) in 50% yield (11.2 g).

7c.—Following removal of the DMF from alkylation of 6 with 5b (69.0-mmole scale) essentially as described for 7b, the residue was stirred with PhMe (200 ml), and the mixture was filtered from NaBr. The filtrate was concentrated under reduced pressure to about 100 ml, and the clarified (Norit, Celite) PhMe solution was diluted with $30-60^{\circ}$ ligroin (400 ml) to precipitate crude **7c**; subsequent recrystallization (H₂O) gave **7c** (52%), mp 100-102° (ir spectrum identical with that of the sample prepared by method A).

Tetrahydro-2H-1,3-oxazin-2-one (11) was prepared from 3chloro-1-propanol and KCNO using the reaction procedure of Phillips and Argabright.¹⁷ Because of difficulties with the reported purification procedure (involving successive recrystallizations from cold Me₂CO) the crude oily product (from a run using 0.250 mole of 3-chloro-1-propanol) was distilled *in vacuo* (15-cm Vigreux column) to give a colorless oil (17.6 g), bp 126-128° (0.1 mm), which crystallized when cooled; recrystallization (EtOAc) gave 11, mp 80–83° (lit.¹⁷ mp 82–83°), in 54% yield (13.6 g); ir (KBr), 3265 (NH) and 1690 cm⁻¹ (C=O). In subsequent runs, 11 of satisfactory purity was obtained by simply allowing it to crystallize from clarified (Norit, Celite) EtOAc solutions of the crude undistilled oil.

3-(3-Phthalimidopropyl)tetrahydro-2H-1,3-oxazin-2-one (14a). —Alkylation of 11 with 5a using the same procedure as described for the preparation of 7b (method B) gave 14a, mp 133-135° (recrystallized once from PhMe), in 62% yield. An analytical sample had mp 135-136° (from PhMe); ir (KBr), 1775 (w), 1710 (s) (imide C==0), and 1675 cm⁻¹ (carbamate C==0). Anal. (C₁₅H₁₅N₂O₄) C, H, N.

3-(4-Phthalimidobutyl)tetrahydro-2H-1,3-oxazin-2-one (14b) was prepared from 11 and 5b by the same procedure as indicated for the preparation of 14a. Pure 14b, mp 146-148° (from PhMe), was obtained in 68% yield; ir (KBr), 1760 (w), 1705 (s) (imide C=O), and 1680 cm⁻¹ (carbamate C=O). Anal. (C₁₆H₁₈N₂O₄) C, H, N.

3-Bromopropylamine Hydrobromide (12).—A solution of 11 (1.00 g, 9.89 mmoles) in 30% HBr-HOAc (5 ml) was stirred at 25-30° for 4 hr while extremely slow reaction occurred as evidenced by evolved CO₂ bubbling from a H₂O-charged gas-absorption trap. Gentle warming caused a marked increase in the rate of CO₂ evolution. The solution was slowly heated to boiling during 1 hr and was maintained under reflux for 10 min. The cooled solution deposited crystalline 12, which was collected with the aid of Et₂O and washed thoroughly with Et₂O before being dried *in vacuo* (77°, P₂O₃). The yield of 12, mp 173–175° (lit. mp 169–172°¹⁸ and 171°^{9c}), was 100% (2.17 g). The melting point, mixture melting point, and ir spectrum of this sample were identical with those of a sample of 12 obtained from a commercial source and purified for use in the preparation of

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TABLE I

Radioprotective Activities of S- ω -(ω -Aminoalkylamino)alkyl Dhydrogen Phosphorothioates and Related Compounds^a

Compd	<i>n'</i>	н	$Y^{t_{p}}$	Approx LD ₅₀ , mg/kg	Drug dose, mg/kg ^c	Vehicle of admin	pH of prepn	- 30-day survival, ∈{ ^d
•			A. $H_{2}N(C)$	H.)./NH(CH.).S	Y			
34	2	2	$PO_{2}H_{2}(\cdot H_{2}O)$	1300	800	Water	6-1	100
	_	_			400	Water	6.1	100
					200	$Saline^r$	6.5	27
					100	Saline	6.5	0
3b	3	2	$PO_{3}H_{2}(\cdot H_{2}O)$	700	600	Water	6.3	86
					300	Water	6.3	86
					150	Water	6.5	40
					7.5	Water	6.5	20
3e	-1	2	PO_3H_2	800	400	Water	7.0	100
					200	Water	7.0	80
					100	Saline	7.6	13
3d	ā	2	$PO_3H_2(\cdot H_2O)$	550	300	Water	6.9	100
					150	Water	6.9	100
			·····		75	Saline	7.2	13
Зe	6	2	$PO_3H_2(\cdot H_2O)$	550 	300	Water	7.0 - 0	87
					200	Saime	$\frac{7.2}{2.0}$	40
					150	water	1.0	96
10	.,	• •	SONT HOD	-00 1000	100	Natur	4.2	0
10a	J	2	$SO_3\Pi(+\Pi OI)$	100~1000	550~700 150-950	Water	0.0 5.9	0
LAI		••	SO 177 17(9)	110	100-000	water	(), ()	0
100	4	2	$SO_3 m(\cdot mO_1)$	·±10	500			0
10.	R	•)	$S(A) H(A H B_{T})$	400	200	Salina	6.9	0
100	0	2	(()3II('IIDI)	400	100	Saline	6.9	0
180	.)	.3	PO ₂ H ₂	1300	100	CMC-Tw/	6.5	100
10a	4	•,	1 (73112	1000	800	CMC-Tw	6.5	83
					500	CMC-Tw	6.5	100
					400	CMC-Tw	6.5	67
					200	CMC-Tw	6.5	13
18b	3	3	$PO_{3}H_{2}(\cdot 2H_{2}O)$	560	320	CMC-Tw	5.5	100
					160	CMC-Tw	5.5	100
					100			100
					75			80
					38			< 10
18c	-1	3	$PO_3H_2(\cdot 2H_2O)$	225	100	Saline	7.1	13
					50	Saline	7.1	0
				CH_3				
			B. $H_2N(C$	CH2)3NHCCH2SY	ŕ			
	12			B				
	11	r	$\mathbf{H}(\mathbf{SHC})$	180	100			67
218 945	11	ſ	SO-H(HCI)	600	100	Water	6.9	0
≙ 10	1,	L	50311(1101)	000	200	Water	6.9	0
210	C	H.	$H(\cdot 2HC1)$	74	-56	CMC-Tw	5.5	0
~ 1 ()	· · ·				28	CMC-Tw	5.5	0
21d	С	Ha	$SO_3H(+HC1)$	1300	1000	CMC-Tw	7.0	17
		0			500	CMC-Tw	7.0	()
23a	11	1	$PO_{3}H_{2}(+2.5H_{2}O)$	4.50	240	Water		50
23b	C	II.	$\mathrm{PO}_{3}\mathrm{H}_{2}(-2.5\mathrm{H}_{2}\mathrm{O})$	900	600	Saline	6.5	87
					300	Water	7.5	80
					120	Saline	6.5	20
					75	Saline	6.5	7
				$\operatorname{CH}_{1}{}_{8}$				
			C. NCCH	₂ CH ₂ NHCH ₂ S	Y			
				${ m \stackrel{!}{R}}$				
24a	Н	I	SO_3H	1300	1000	CMC-Tw	5.5	0
			-		500	CMC-Tw	5.5	0
24b	C	'H ₃	$H(\cdot HCI)$	320	180	CMC-Tw	5.5	0
					90	CMC-Tw	5.5	()
$24\mathrm{c}$	C	$2 \Pi_a$	SO3H	1800	1000	CMC-Tw	5.5	
					500	CMC-Tw	5.5	17

TABLE I (Continued)

Compd	Structure		Approx LD50, mg/kg	Drug dose, mg/kg¢	Vehicle of admin	pH of prepn	30-day survival, % ^d
		D.	Others				
13	$H_2N(CH_2)_3SPO_3H_2$		430	320	CMC-Tw	5.5	17
				160	Water	5.5	13
				125	CMC-Tw	5.7	13
				62.5	CMC-Tw	5.7	7
26	NCCH2CH2NHCH2CH2SPO3HNa		500	200	CMC-Tw	6.7	0
				100	CMC-Tw	6.7	0

^a Antiradiation screening tests in mice against lethal radiation [825 R (X-rays) or 950–1050 R (γ rays)] were performed at Walter Reed Army Institute of Research, Washington, D. C., under the direction of Dr. D. P. Jacobus. ^b Water of crystallization and characterization as hydrohalide salts indicated in parentheses. ^c Drug injected intraperitoneally as 0.3–5.0% solution or suspension 15–30 min before irradiation. ^d No 30-day survival among control mice. ^e Physiological saline solution. ^f Compound dissolved or suspended in physiological saline solution containing 0.3% sodium carboxymethylcellulose and 0.1% Tween 80.

13 by successive recrystallizations from MeCN and MeOH-Et_2O.

N- $[\omega$ - $(\omega$ -Bromoalkylamino)alkyl]phthalimide hydrobromides (8, 15) listed in Table II were prepared from the appropriate 7 or 14 as illustrated by the following procedures.

A. 8a and 8b.—A solution of 7a (39.5 g, 0.152 mole) in 30%HBr-HOAc (200 ml) was stirred at 25-30° for 21 hr. Et₂O (700 ml) was added, and the collected precipitate was recrystallized from EtOH. Similar treatment of 7b afforded 8b, which was recrystallized from 95% EtOH.

B. 8c, 15a, and 15b.—A stirred mixture of 14b (20.0 g, 66.2 mmoles) in 30% HBr-HOAc (125 ml) was gradually heated to reflux during 90 min. Following a 30-min reflux period, the mixture was allowed to cool, and Et₂O (500 ml) was added; and the product was recrystallized from EtOH. Similarly obtained 8c and 15a were recrystallized from MeOH and 95% EtOH, respectively.

N-(2-Bromoethyl)- α , ω -alkanediamine dihydrobromides (2) were prepared from 1 essentially by the Cortese method.⁸ The HBr remaining after the reaction period was removed under reduced pressure, and the crystalline residue was stirred with Me₂CO, collected, and recrystallized from MeOH-Me₂CO. Results are given in Table III.

N-(3-Bromopropyl)- α , ω -alkanediamine dihydrobromides (17) were prepared as follows with yields and characterizations being recorded in Table III.

A. 17a.—A solution of 16a (12.8 g, 0.108 mole) in 48% HBr (500 ml) was refluxed 1 hr, then slowly distilled during 12 hr until 400 ml of distillate had been collected. The remaining solution was evaporated to dryness under reduced pressure, and the solid residue was reprecipitated from MeOH solution by addition of EtaO.

B. 17b.—A solution of 15a (13.0 g, 32.0 mmoles) in 48% HBr (50 ml) and glacial AcOH (50 ml) was refluxed 17 hr, cooled while phthalic acid separated, and filtered. Removal of solvents from the filtrate by evaporation under reduced pressure left crystalline 17b, which was purified by reprecipitation from MeOH solution by addition of Et_2O followed by recrystallization from EtOH.

C. 17c was obtained from 15b by the same procedure as described for the preparation of 17b.

1-(4-Aminobutyl)ziridine (9b).—Pulverized 1c (100 g, 0.280 mole) was added in portions to stirred 20% NaOH solution (800 ml). The stirred mixture was refluxed for 1 hr and allowed to cool, and the two liquid layers were separated. The aqueous layer was extracted with three 100-ml portions of Et₂O; the dried (MgSO₄) Et₂O solution was evaporated to an oil, which was combined with the organic phase from the reaction mixture. The crude product was dried (KOH) and fractionally distilled (Vigreux column) to give 9b, bp 79-80° (20 mm) and n^{22} D 1.4587, in 70% yield (22.3 g); purity by glpc was >99%. Anal. Calcd for C₆H₄N₂: C, 63.11; H, 12.36; N, 24.53. Found: C, 61.72; H, 12.03; N, 24.09.

2-Methyl-1-aziridinepropionitrile (19a).—2-Methylaziridine (100 g, 1.75 moles) was added dropwise to stirred acrylonitrile (93.3 g, 1.76 moles) preheated to 65° ; the temperature was maintained at $65-70^{\circ}$ throughout the addition period and for about 1 hr afterward by moderate cooling. When heat ceased to be evolved, the mixture was heated at $70-75^{\circ}$ for 2 hr. Fractionation (30-cm Vigreux column) afforded 19a, bp $70-72^{\circ}$ (10 mm)

TABLE II

N-[ω -(ω -Bromoalkylamino)alkyl]Phthalimide Hydrobromides (8, 15)

No.	Yield, %	Mp, °C dec	Formula	Analyses
8a	82	190 - 192	$C_{12}H_{13}BrN_2O_2 \cdot HBr$	C, H, Br
8b	82	225 - 227	$\mathrm{C}_{13}\mathrm{H}_{15}\mathrm{BrN}_{2}\mathrm{O}_{2}\cdot\mathrm{HBr}$	C, H ₂ Br
8c	94	229 - 231	$\mathrm{C}_{14}\mathrm{H}_{17}\mathrm{BrN}_{2}\mathrm{O}_{2}\cdot\mathrm{HBr}$	C, H, Br, N
15a	89	199 - 200	$\mathrm{C}_{14}\mathrm{H}_{17}\mathrm{BrN}_{2}\mathrm{O}_{2}\cdot\mathrm{HBr}$	C, H, Br, N
15b	91	192 - 196	$\mathrm{C}_{15}\mathrm{H}_{19}\mathrm{BrN}_{2}\mathrm{O}_{2}\cdot\mathrm{HBr}$	C, H, Br, N

TABLE III

N-(2-BROMOETHYL)- α , ω -Alkanediamine Dihydrobromides (2), N-(3-BROMOPROPYL)- α , ω -Alkanediamine Dihydrobromides

> (17), AND N-(2-BROMOALKYL)-1,3-PROPANEDIAMINE DIHYDROBROMIDES (22)

YDROBROMIDES (2	
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	Yield,			
No.	%	Mp, °C	Formula	Analyses
2a	85	174–176ª	$C_4H_{11}BrN_2 \cdot 2HBr$	C, H, Br ^b
$2\mathrm{b}^{\mathfrak{o}}$	80	$205 - 206^{a}$	$C_5H_{13}BrN_2 \cdot 2HBr$	C, H, Br
2c	78	200-201ª	$C_6H_{15}BrN_2 \cdot 2HBr$	C, H, Br
2d	86	$183 - 185^{a}$	$C_7H_{17}BrN_2 \cdot 2HBr$	C, H, Br
2e	84	$176 - 178^{a}$	$C_8H_{19}BrN_2 \cdot 2HBr$	C, H, Br
17a	81	144 - 145	$C_5H_{13}BrN_2 \cdot 2HBr$	C, H, Br, N
17b	83	243 - 245	$C_6H_{15}BrN_2 \cdot 2HBr$	C, H, Br, N
$17 c^d$	79	227 - 229	$C_7H_{17}BrN_2 \cdot 2HBr$	C, H, Br, N
22a	37	211 - 212	$C_6H_{15}BrN_2 \cdot 2HBr$	C, H, Br
22b	54	188 - 189	$C_7H_{17}BrN_2 \cdot 2HBr$	C, H, Br

^a Determined on a Kofler Heizbank. ^b Br: calcd, 72.89; found, 73.5. ^c The sample prepared from **1b** was not analyzed; it is identical (melting point, mixture melting point) with an analytically pure sample prepared in nearly theoretical yield by ring opening of **9a** in the manner described for the preparation of **22b**. Pure **2b** was also prepared in 92% yield from **8b** using the procedure described for **17b**. ^a Also prepared from **16b** in 62% yield using the procedure described for **17a**.

and n^{24} D 1.4368, in 80% yield (155 g). Anal. (C₆H₁₀N₂) H, N; C: calcd, 65.42; found, 64.82.

2,2-Dimethyl-1-aziridinepropionitrile (19b).—A solution of 2,2-dimethylaziridine (100 g, 1.41 moles) and acrylonitrile (64.7 g, 1.20 moles) was refluxed for 12 hr, the reflux temperature gradually rising during this period from 78 to 138°. Fractionation (30-cm Vigreux column) afforded 19b, bp 81-89° (11 mm) and n^{25} D 1.4419, in 63% yield (94.2 g). An analytical sample, bp 78-81° (10 mm) and n^{27} D 1.4406, was obtained in 19% yield employing the conditions described by Bestian for the preparation of 1-aziridinepropionitrile.⁶ Anal. (C₁H₁₂N₂) C, H, N.

1-(3-Aminopropyl)aziridine (9a), 1-(3-Aminopropyl)-2-methylaziridine (20a), and 1-(3-Aminopropyl)-2,2-dimethylaziridine (20b).—LiAlH₄ reductions of the appropriate nitriles (1-aziridinepropionitrile, 6 19a, and 19b) were performed according to a general procedure described by Amundsen and Nelson.¹⁹ Pure 9a,

⁽¹⁹⁾ L. H. Amundsen and L. S. Nelson, J. Amer. Chem. Soc., 73, 242 (1951).

S-2-(ω-Aminoalkylamino)ethyl Hydrogen Thiosulfate Hydrohaldes (10), S-2-(3-Aminopropylamino)alkyl Hydrogen Thiosulfate Hydrochlorides (21b+HCl, 21d+HCl),

and S-2-(2-Cyanoethylamino)alkyl Hydrogen

L	н	н	15	υı	чF	.7	TE:	5 (24	а,	240	С.	Ł

	Yield,	Μр,		
No,	Se .	° C	Formula	Analyses
10a	95	87-90	$\mathrm{C}_{5}\mathrm{H}_{14}\mathrm{N}_{2}\mathrm{O}_{3}\mathrm{S}_{2}\cdot\mathrm{HCl}$	C, H, N, S
10b	98	79 - 89	$\mathrm{C_6H_{16}N_2O_3S_2}\cdot\mathrm{HCl}$	C, H, S; N ^a
[0e	50	149^{6}	$\mathrm{C_8H_{20}N_2O_3S_2\cdot HBr}$	C, H, Br, S
$21b \cdot HCl$	88	e	$C_6H_{16}N_2O_3S_2\cdot HCl$	C, H, N, S
$21d \cdot HCl$	86	c	$\mathrm{C_7H_{18}N_2O_3S_2\cdot HCl}$	С, Н, N, S
24a	51	214^{b}	$C_6H_{12}N_2O_3S_2$	C, H, N, S
24c	46	240^{5}	$C_7H_{14}N_2O_3S_2$	C, H, N, S
« N· cal	ed = 10.58	• found	10.16 ^b Determine	d on a Kofler

" N: calcd, 10.58; found, 10.16. " Determined on a Koffe Heizbank. "Indefinite.

bp 58-60° (19 mm) [lit.⁶ bp 61-62° (19 mm)], was obtained in 38% yield. The yield of **20a**, bp 72-75° (40 mm) and n^{23} D 1.4466, was 68% and that of **20b**, bp 84-86° (30 mm) and n^{27} D 1.4485, was 74%. Anal. (C₆H₁₄N₂, **20a**) C, H, N. (C₇H₁₆N₂, **20b**) C, H, N.

N-(2-Bromo-1-methylethyl)-1,3-propanediamine dihydrobromide (22a) was prepared by dropwise addition of 20a (26.0 g, 0.236 mole) to stirred 48% HBr (105 ml) maintained at -5 to 0°. The clear solution was evaporated to dryness under reduced pressure with the aid of several added portions of MeOH. The residual gum was stirred with boiling EtOAc (1 l.) for 1 hr, and crystalline 22a formed while the stirred mixture was allowed to cool. The crude material was collected, dried (*in vacuo*, 80°, P₂O₆), and recrystallized from *i*-PrOH (1.5 l.) to give pure 22a. Results are recorded in Table III.

N-(2-Bromo-1,1-dimethylethyl)-1,3-propanediamine dihydrobromide (22b) (see Table III) was prepared by HBr ring opening of 20b in the manner described for 22a from 20a. Following evaporation to dryness, the solid residue was stirred with Me₂CO. The collected, Me₂CO-insoluble solid was purified by one recrystallization (MeOH-Me₂CO) followed by two reprecipitations from MeOH solution by addition of Et_2O .

S-2-(ω -Aminoalkylamino)ethyl Hydrogen Thiosulfate Hydrochlorides (10a, 10b).—The following description of the preparation of 10b is typical of the procedure used; results are recorded in Table IV. A solution of 9b (1.90 g, 16.6 mmoles) and (NH₄)₂-S₂O₃ (2.46 g, 16.6 mmoles) in H₂O (10 ml) was evaporated (aspirator) during 1 hr in a bath gradually heated to 90°. Last traces of volatile material were then removed *in vacuo* (1 mm) at 60° (30 min). The residual syrup was dissolved in H₂O (10 ml), and the solution was treated with 1 N HCl (16.6 mequiv). The resultant solution of 10b was evaporated to dryness, final conditions being 1 mm, 60°. Drying was completed *in vacuo* at 25-30° over P₂O₅.

S-2-(6-Aminohexylamino)ethyl Hydrogen Thiosulfate Hydrobromide (10c).—A solution of equimolar amounts of Na₂S₂O₃· 5H₂O, NaOAc·3H₂O, and **2e** (40.0 mmoles each) in H₂O (40 ml) and DMF (20 ml) was kept at 25-30° for 2 hr and then at 90– 100° for 1 hr. Solvents were removed under reduced pressure, and the residue was dissolved in boiling EtOH (about 500 ml). Crystalline material that separated during a 4-day period was collected and recrystallized again from EtOH. The material obtained, now pale-yellow, was dissolved in boiling MeOH; the hot solution was decolorized (Norit, Celite), then evaporated under reduced pressure to a colorless syrup, which crystallized readily when stirred with warm (50°) EtOH (100 ml) to give pure 10c (dried *in vacuo*, 25-30°, P₂O₅) (Table IV).

S-2-(3-Aminopropylamino)propyl Hydrogen Thiosulfate (21b) and S-2-(3-Aminopropylamino)-2-methylpropyl Hydrogen Thiosulfate (21d) Hydrochlorides.—The following procedure for the preparation of 21b·HCl is illustrative; results are given in Table IV. A solution of 20a (2.67 g, 23.4 mmoles) and (NH₄)₂S₂O₃ (3.30 g, 22.3 mmoles) in H₂O (15 ml) was evaporated during 1 hr (aspirator, 35° bath). The residual syrup was redissolved in H₂O (15 ml), and evaporation under the same conditions was repeated. The residue was then subjected to 0.2 mm, bath temperature 100°. The pasty residue was dissolved in H₄O (15 ml), TABLE V

S-2-(ω-Aminoalkylamino)ethyl Dihydrogen
 Phosphorothioates (3a/3e), S-3-(ω-Aminoalkylamino)propyl
 Dihydrogen Phosphorothioates (18a/18c), and

8-2-(3-AMINOPROPYLAMINO)ALKYL DHIYDROGEN

Phosphorothioates (23a, 23b)

No.	Scale, mmoles of Na3PSO3	Yield,	${}^{\mathrm{Mp,\ ^{\circ}C}}_{\mathrm{dee}}$	Formula	Analyses
За	50.0	82	139 - 141	$C_4H_{13}N_2O_3PS \cdot H_2O$	C. H. N. S
$^{3\mathrm{b}}$	38 5	91	$-160 - 161^{st}$	$C_5H_{15}N_2O_3PS \cdot H_2O$	C, H, N
3e	35 4	71		$C_6H_{17}N_2O_8PS$	C. H. N. S
3d	37 8	67	h_{i}	$C_7H_{19}N_2O_3PS \cdot H_2O$	C, H, N, S
Зe	50.0	33	5	$C_5H_{21}N_2O_8PS\cdot 2H_2O$	C, H, N, S
18a	<i>(*</i>	81	168 - 170	$C_5H_{15}N_2O_3PS$	C, H, N, P, S
18b		92	140 - 143	$C_6H_{17}N_2O_3PS\cdot 2H_2O$	C, H, N, P, S
18c		67	171 - 172	$C_7H_{19}N_2O_3PS\cdot 2H_2O$	C, H, N, P, S
23a		78	122 - 124	$C_6H_{17}N_2O_8PS \cdot 2.5H_2O$	C, H, N, P, S
23b		93	149 - 154	$C_7H_{19}N_2O_3PS\cdot 2,5H_2O$	-C, H, N; P, 86

^a Determined on a Kofler Heizbank. ^b Indefinite melting point with decomposition over wide range (starting about 470°) dependent on rate of beating. ^c For remaining entries molar scales are stated in the procedures. ^d Anal. Calcd: P, 10.79; S, 11.16. Found: P, 11.2; S, 11.6.

and 1 N HCl (22.3 mequiv) was added; **21b** HCl was then isolated in the same way as **10b** described above.

S-2-(2-Cyanoethylamino)propyl Hydrogen Thiosulfate (24a). A solution of 19a (2.89 g, 26.3 mmoles) and $(NH_4)_2S_2O_3$ (3.71 g, 25.0 mmoles) in H₂O (15 ml) was evaporated (aspirator, bath temperature 40°). A solution of the residue in H₂O (15 ml) was again evaporated to dryness, and the product was further purified by reprecipitation from H₂O with EtOH. Results are included in Table IV.

S-2-(2-Cyanoethylamino)-2-methylpropyl hydrogen thiosulfate (24c) (see Table IV) was prepared from 19b by essentially the same procedure as described for 24a except that 24c was recrystallized from MeOH.

2-(3-Aminopropylamino)-1-propanethiol (21a), 2-(3-Aminopropylamino)-2-methyl-1-propanethiol (21c) Dihydrochlorides, and 3-(2-Mercapto-1,1-dimethylethylamino)propionitrile (24b) Hydrochloride.-Preparation of these compounds involved H2S ring opening of the appropriate aziridine 20a, 20b, or 19b. The procedure for preparing 21a · 2HCl is illustrative. MeOH (75 ml) was saturated with H_2S at -10° . A slow stream of H_2S was passed through the stirred solution while $\mathbf{20a}$ (3.00 g, 26.3 mmoles) was added dropwise. The resultant solution was kept at -5° for 30 min and then refrigerated (at about 4°) overnight in a securely stoppered flask. The solution was then concentrated under reduced pressure to 25 ml and treated with dry HCl in EtOH (9.5 ml of 6.35 N, 60 mequiv HCl). Addition of Et_2O (75 ml) afforded crystalline 21a·2HCl, which was collected and dried in vacuo (25-30°, P_2O_5); yield 98% (5.69 g), mp ~156°. Anal. (C₆H₁₆N₂S·2HCl) C, H, N, S, SH. Similar treatment of **20b** afforded **21c**·2HCl, mp 182-183°, in 73% yield after recrystallization from EtOH. Anal. (C₇H₁₈N₂S·2HCl) C, H, N, S, SH. The yield of **24b**·HCl, mp 163°, was 72% (from 24.2 mmoles of **19b**, 25.4 mequiv of HCl being used). *Anal.* (C₇H₁₄N₂S·HCl) C, H, N, S; SH: caled, 16.98; found, 15.9.

S-2-(ω -Aminoalkylamino)ethyl Dihydrogen Phosphorothioates (3).—The general reaction procedure used is essentially that described by Åkerfeldt⁹⁴ for the preparation of related compounds. A stirred partial solution of Na₃PSO₃ in H₂O (1 ml/ mmole of Na₃PSO₃) was treated with the appropriate 2 (3 6 mole $\frac{27}{6}$ excess). When solution was complete, DMF (one-half the volume of H₂O used) was added with external cooling; the resultant solution was kept at 25–30° until the AgNO₅ test for unchanged PSO₄³⁻⁹e was negative. Isolation procedures used for the individual examples listed in Table V follow.

3a was the only member of the **3** series that crystallized directly from the reaction solution. The solid was collected, washed (MeOH-H₂O, 4:1 by vol), then dissolved (H₂O, 400 ml) and reprecipitated by addition of MeOH (11.). Following overnight refrigeration, crystalline **3a** was collected, washed (MeOH, Et₂O), and air dried.

3b.—Dilution of the reaction solution with MeOH (250 ml) caused precipitation of white solid; following overnight refrigeration, the solid was collected, dissolved (H₂O, 40 ml),

and reprecipitated with MeOH (250 ml). The collected solid was washed (MeOH, Et_2O), and air dried.

3c was precipitated by addition of MeOH (175 ml), reprecipitated from H_2O -MeOH, then dried *in vacuo* (P_2O_5) for about 5 min at 80° followed by several hours at 25-30°. This material showed no tendency to gain weight when exposed to ambient conditions.

3d.—MeOH (200 ml) was added to the reaction solution, but no precipitate formed. EtOH (200 ml) was then added, and a white, somewhat gelatinous solid formed. After overnight refrigeration the solid was collected, washed (MeOH), and then stirred with MeOH (200 ml) for 1.5 hr. The solid that remained was collected, dissolved in H_2O (20 ml), and reprecipitated by addition of MeOH (100 ml) followed by EtOH (100 ml). After refrigeration (18 hr), the solid was collected, washed (MeOH), and dried *in vacuo* (80°, P_2O_5). Marked shrinkage occurred before the sample came to constant weight (6.20 g). Equilibration with ambient conditions caused a weight increase (to 6.62 g).

3e.—Essentially the same procedure as used in the isolation of **3b** sufficed.

S-3-Aminopropyl dihydrogen phosphorothioate (13), mp 293–295° dec, was prepared in 36% over-all yield *via* its uncharacterized monosodium salt (from 12 and Na₃PSO₃) using the methods described for the S-2-aminoethyl homolog^{9b} (Åkerfeldt^{9c} has described preparation of the monolithium salt of 13). Anal. (C₃H₁₀NO₃PS) C, H, N, P, S.

S-3- $(\omega$ -Aminoalkylamino)propyl dihydrogen phosphorothioates (18), which are included in Table V, were prepared as follows.

18a.—A stirred solution of Na₃PSO₃ (3.60 g, 20.0 mmoles) and 17a (6.86 g, 20.0 mmoles) in H_2O (20 ml) was treated with DMF (10 ml), and stirring was continued 1.5 hr while crystalline 18a separated. Addition of EtOH (200 ml) followed; the collected, EtOH-washed precipitate was redissolved in H_2O (50 ml), then reprecipitated by addition of MeOH (~35 ml to cause incipient cloudiness). Crystalline 18a that separated during refrigeration was collected, washed (MeOH- H_2O , Et₂O), and air dried.

18b.—A solution of equimolar amounts of 17b and Na₃PSO₃ (10.0 mmoles each) in H₂O (10 ml) was kept at 25–30° for 2 hr, then stored overnight in a refrigerator ($\sim 4^{\circ}$). The still-cold solution was stirred while DMF (5 ml) was added, and crystalline 18b separated immediately. EtOH (100 ml) was added, and the solid was collected, washed (EtOH), redissolved in H₂O (60 ml), then reprecipitated by addition of EtOH (50 ml to cause incipient cloudiness). Following refrigeration, the lustrous platelets were collected, washed (EtOH), and dried *in vacuo* (25–30°, NaOH pellets).

18c.—A stirred solution of Na₃PSO₂ (2.70 g, 15.0 mmoles) and 17c (5.60 g, 15.1 mmoles) in H₂O (15 ml) was treated with DMF (7.5 ml). The resultant solution was kept at 25–30° for 2 hr, then added dropwise to rapidly stirred EtOH (450 ml). The solid that separated was collected, washed (EtOH), then suspended in rapidly stirred MeOH (25 ml). H₂O (\sim 15 ml) was added slowly until nearly all of the solid had dissolved. More MeOH (50 ml) was then added causing crystalline product to separate. The collected material was washed (MeOH) and dried *in vacuo* (25-30°, P_2O_5). Equilibration with ambient conditions ($\sim 50\%$ relative humidity) caused a weight increase (from 2.60 to 2.81 g).

S-2-(3-Aminopropylamino)propyl Dihydrogen Phosphorothioate (23a).—Solid 22a (5.25 g, 14.7 mmoles) was added to a stirred solution of $Li_3PSO_3 \cdot 6H_2O$ (3.36 g, 14.0 mmoles) in H_2O (28 ml), and, after solution was complete, DMF (14 ml) was added. The solution was kept at 25-30° for 40 min and then poured into EtOH (400 ml). Solvated 23a separated as an opaque gum. The supernatant was removed by decantation, and the gum was dissolved in H_2O (50 ml). The solution was added dropwise to rapidly stirred EtOH (500 ml), but the solvated product again separated as white opaque gum. Following removal of the supernatant, the residue was dissolved in H_2O (20 ml); EtOH (50 ml) was added to the stirred solution. After a few minutes of rapid stirring, the cloudy mixture began depositing crystalline material. More EtOH (450 ml) was added, and stirring was continued 1 hr. The crystalline product was collected, washed with EtOH followed by Et₂O, air dried (3.04 g), and equilibrated at constant 58% relative humidity⁴ (equilibrated weight, 2.97 g). Results are included in Table V.

S-2-(3-Aminopropylamino)-2-methylpropyl Hydrogen Phosphorothioate (23b).—A solution of 22b (4.45 g, 12.0 mmoles) and Li₃PSO₃·6H₂O (2.88 g, 12.0 mmoles) in H₂O (12 ml) was stirred at 25–30° for 30 min. DMF (6 ml) was added, and, after 15–20 min, the solution began depositing crystalline product. The mixture was refrigerated overnight, EtOH (60 ml) was added, and the precipitate was collected, washed (EtOH), redissolved in H₂O (20 ml), then reprecipitated by addition of EtOH (100 ml). Hydrated 23b was collected, washed (EtOH, Et₂O), air dried (3.18 g), and equilibrated at 58% relative humidity⁴ (equilibrated weight, 3.21 g.). Results are included in Table V.

S-2-(2-Cyanoethylamino)ethyl Sodium Hydrogen Phosphorothioate (26) Tetrahydrate.—A mixture of equimolar amounts of 25 and Na₃PSO₃ (40.0 mmoles each) in H₂O (40 ml) was stirred until solution had occurred (20 min). DMF (20 ml) was added, and the solution was stirred at 25–30° for 1 hr. Dropwise addition of EtOH (150 ml) with chilling (ice-water bath) and continued stirring caused separation of hydrated 26 as a white solid, which was collected, redissolved in H₂O (40 ml), and reprecipitated by addition of EtOH. The collected product was washed (EtOH, Et₂O) and air dried; yield 81% (9.85 g). Anal. (C₅H₁₀N₂NaO₃PS·4H₂O) C, H, S; N: calcd, 9.21; found, 8.62; P: calcd, 10.18; found, 10.6.

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