The minor reaction product **8** was present as an impurity in the crude eniminocarboxylic acid **4**, as shown by ultraviolet spectroscopy (*cf.* Experimental Section); **8** was most probably formed by the rearrangement of **4** to intermediate D, followed by acetylation of the latter by acetyl chloride (eq 1). The rearrangement bears some resemblance to the conversion of **1** into **2** and adds further support to the postulated structure of intermediate **4**.

Experimental Section[9]

1,2,3,4,9,10-Hexahydro-7-oxo-7-methoxy-2-phenanthrenecarboxylic Acid (5).—To 42 ml of acetyl chloride was added with stirring 4.05 g of the oxime acid (**3**).[4] The flask was stoppered and the reaction mixture was stirred at 20° for 16 hr. A small sample (0.2 ml) was taken to dryness *in vacuo*, and the residual solid was suspended in petroleum ether (bp 30–60°). Filtration gave 31 mg (98%) of the crude imine hydrochloride **4**: mp 72–75° dec; λ_{max} 209 mμ (ε 17,300), 233 (10,150),[10] and 254 (10,070); ν_{max}^{KBr} 2940 (very broad, salt band), 1700 (carboxyl carbonyl), and 1620 cm^{-1} (α,β-unsaturated imine).

The remaining portion of the reaction mixture was poured on ice without the isolation of the intermediate **4**. Enough acetone was added to dissolve the precipitate, and it was stirred under nitrogen at 20° for 16 hr. About one-third of the solvent was then removed *in vacuo*. After standing for 2 hr at 20° a crystalline precipitate formed. It was filtered to give 2.55 g (66.8%) of the crude unsaturated keto acid **5**, mp 208–210°. Recrystallization from acetone gave analytically pure **5**: mp 210–211.5°; λ_{max} 246 mμ (ε 17,400), 292 (4840), and 311 (4320); ν_{max}^{KBr} 1705 (carboxyl carbonyl) and 1663 cm^{-1} (α,β-unsaturated ketone); nmr (C_5D_5N) multiplet at δ 2.25 and 2.57 ($-CH_2CH_2-$, J = 7 cps), multiplet at 2.85 ($-CH_2CHCH_2CO-$), singlet at 3.65 (CH_3O) multiplet at 6.70 (3 H, aromatic), and broad singlet at 11.0 (COOH)

Anal. Calcd for $C_{16}H_{16}O_4$: C, 70.57; H, 5.92. Found: C, 70.59; H, 5.76.

4β-Acetamido-1,2,3,4-tetrahydro-7-methoxy-2α-phenanthrenecarboxylic Acid (8).—Filtration of the 2.55 g of crude **5** gave an acetone and water-containing mother liquor. The acetone was evaporated *in vacuo*, and the water was extracted with ethyl acetate. The extract was washed free of mineral acid, dried with sodium sulfate, and evaporated *in vacuo* to yield 1.24 g of an amorphous powder. Crystallization from acetone and petroleum ether (bp 30–60°) gave 0.76 g of a solid, which was recrystallized from chloroform, to give 131 mg of analytically pure **8**: mp 232–3°; λ_{max} 231 mμ (ε 61,500), 263.5 (5380), 273 (5750), 283 (4040), 320 (2120) and 334.5 (2600); ν_{max}^{KBr} 1720 (carboxyl carbonyl), 1630 cm^{-1} (amide carbonyl); nmr (C_5D_5N) singlet at δ 1.94 (CH_3CON), multiplet at 2.60–3.50 ($-CH_2CHCH_2-$), singlet at 3.77 (CH_3O), quartet at 5.98 (C-4 proton, $J_{4H,NH}$ = 7.5 cps and $J_{3H,4H}$ = 5.5 cps), broad multiplet at 7.10–7.75 (four aromatic protons, and COOH), multiplet at 8.05 (1 H, aromatic), and doublet at 8.25 (HN–CO). The high resolution mass spectrum showed a molecular ion at m/e 313 ($C_{18}H_{19}NO_4$). The major fragment ions were observed at m/e 295 ($C_{18}H_{17}NO_3$), 254 ($C_{16}H_{14}O_3$), 209 ($C_{15}H_{13}O$), 194 ($C_{14}H_{10}O$), 178 ($C_{14}H_{10}$), and 165 ($C_{13}H_9$).

Anal. Calcd for $C_{18}H_{19}NO_4$: C, 68.99; H, 6.11; N, 4.47. Found: C, 69.06; H, 6.16; N, 4.55.

Sodium Borohydride Reduction of the Unsaturated Keto Acid 5.—To 8.4 mg of **5** in 2 ml of absolute ethyl alcohol was added 2 mg of sodium borohydride. After stirring for 2 hr at 20° it was poured into 2 ml of ice water. Most of the alcohol was evaporated *in vacuo*, and the water solution was extracted with ethyl acetate. The extract was dried over sodium sulfate, and evaporated *in vacuo* to give 6.1 mg of an amorphous solid (**6**), λ_{max} 271 mμ (ε 17,070).

1,2,3,4,4aβ,9,10,10aβ-Octahydro-7-methoxy-4-oxo-2α-phenanthrenecarboxylic Acid (7).—To 54.5 mg of the unsaturated keto acid **5** in 3.8 ml of absolute ethyl alcohol was added 17.4 mg of morpholine in 1.7 ml of absolute ethyl alcohol. The morpholine salt of **5** formed was hydrogenated at 20° and atmospheric pressure in the presence of 11.0 mg of 10% palladium on barium sulfate catalyst. After the uptake of 1 mole of hydrogen, the catalyst was filtered and the alcohol solution was evaporated to dryness *in vacuo* to give 75 mg of an amorphous solid. Crystallization from a small amount of absolute ethyl alcohol gave 36.1 mg of the morpholine salt of **7**, mp 153.5–154°. This salt was dissolved in 0.5 ml of water, and 1 drop of 2 *N* hydrochloric acid was added. The crystalline precipitate was filtered and dried *in vacuo* at 40° for 6 hr. Recrystallization from a small amount of acetone gave 20 mg of the *cis* keto acid **7**, mp 171–173°.

Registry No.—**4**, 15378-22-0; **5**, 15378-23-1; **7**, 1987-81-1; **8**, 15378-25-3.

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(8) Z. G. Hajos, D. R. Parrish, and M. W. Goldberg, *J. Org. Chem.*, **31**, 713 (1966).

(9) All melting points were determined with a Thomas–Hoover melting point apparatus and are corrected. All ultraviolet spectra were taken in ethyl alcohol with a Cary 14M spectrophotometer. Infrared spectra were taken with a Beckman IR-9 spectrophotometer. Nmr spectra were taken with a Varian HA-100 spectrometer at 100 Mc/sec and tetramethylsilane as an internal standard.

(10) The band at 233 mμ indicates approximately 19% of **8** as an impurity.

2-Amino-2-thiazoline. IV.[1] The Ring Opening of 2-Amino-2-thiazolines and 2-Amino-2-selenazoline with Hydrogen Sulfide to Form Thiourea Derivatives

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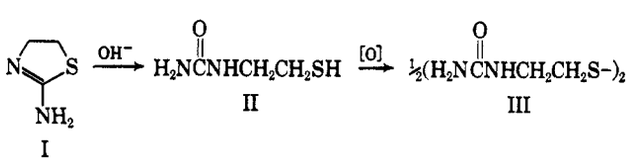
Schöberl, *et al.*,[2] reported that 2-amino-2-thiazoline (I), when heated for 0.5 hr with 2 *N* sodium hydroxide solution, ring opened to give 2-(mercaptoethyl)urea



I II III

(II). Oxidation of the latter compound with 3% hydrogen peroxide solution gave the corresponding disulfide (III). This alkali treatment followed by peroxide oxidation has been applied also to 2-amino-5,6-dihydro-4H-1,3-thiazine (IV, 2-aminopentathiazoline)[3] and to 2-amino-2-selenazoline[4] to give 1,1′-[dithiobis(trimethylene)]diurea and 1,1′-(diselenodiethylene)-diurea, respectively. Resistance to the action of aqueous alkali was encountered, however, in attempts

(1) Part III: D. L. Klayman, J. J. Maul, and G. W. A. Milne, *Tetrahedron Letters*, 281 (1967).

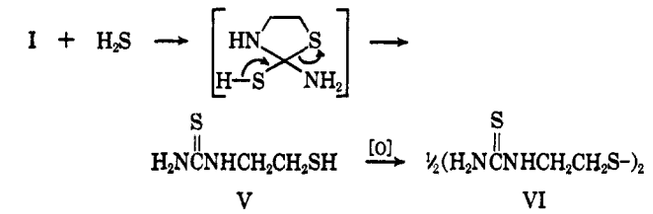
(2) A. Schöberl and M. Kawohl, *Monatsh.*, **88**, 478 (1957); A. Schöberl and G. Hansen, *Chem. Ber.*, **91**, 1055 (1958).

(3) A. Schöberl, M. Kawohl, and G. Hansen, *Ann.*, **614**, 83 (1958).

(4) L. V. Pavlova and F. Yu. Rachinskii, *Zh. Obshch. Khim.*, **35**, 492 (1965).

to hydrolyze 2-imino-3-methylthiazolidine.[5] When the alkaline hydrolysis of this compound was performed in a sealed tube at 150°, carbon dioxide and hydrogen sulfide were the only identifiable products. 2-Hydrazino-2-thiazoline[6] has also been reported to be unaffected by aqueous alkali.

We have found that the action of hydrogen sulfide on I in aqueous or ethanolic solution gives 1-(2-mercaptoethyl)-2-thiourea (V). This compound gives a positive

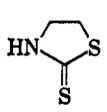


V VI

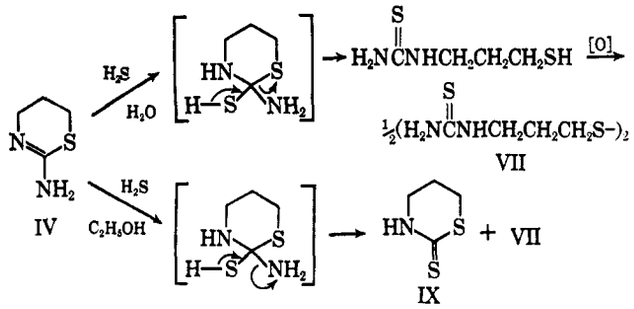
nitroprusside test for a thiol, shows a peak in the infrared at 4.03 μ (SH), and reacts with ammoniacal silver nitrate solution to form a black precipitate of silver sulfide, indicative of a thiourea.[7] Compound V and related mercaptoethylthioureas which were obtained were generally accompanied by their corresponding disulfides. The thiol forms, when isolated, were found difficult to recrystallize because of their tendency to air oxidize readily. Since the purpose of this study was to determine the scope of the ring-opening reaction, it was found convenient to oxidize the product directly with hydrogen peroxide to give the stable disulfide form. Compound V was, however, isolated in a pure state.

Derivatives of I, having either an alkyl or phenyl substituent on the 2-amino group, were found to open readily with hydrogen sulfide. The 3-methyl derivative of I and 2-hydrazino-2-thiazoline, mentioned above for their failure to open on alkaline hydrolysis, were susceptible to the action of hydrogen sulfide. 1,1′-(Dithiodiethylene)bis(3-methyl-2-thiourea) and 4,4′-(dithiodiethylene)bis(3-thiosemicarbazide) were obtained, respectively, after oxidation. The six-membered homolog of I (IV) gave 1,1′-[dithiobis(trimethylene)]bis(2-thiourea) (VII). The disulfides and compound V, made by the ring-opening reaction, showed bands in the infrared which have been described by Jensen and Nielsen[8] as being characteristic of thioureas.

A solvent effect was observed when anhydrous ethanol was used as the reaction medium for the hydrogen sulfide ring-opening. The reaction of I with hydrogen sulfide in ethanol gave a small quantity of 2-thiazolidinethione (VIII), in addition to V and VI, presumably, with the concomitant loss of ammonia. Similarly, IV gave tetrahydro-1,3-thiazine-2-thione (IX) in addition to the products resulting from ring-opening.



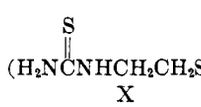
VIII



IV IX

No thione was detectable by tlc when the reaction of hydrogen sulfide with I or IV was performed in water.

The action of hydrogen sulfide on 2-amino-2-selenazoline in aqueous solution followed by air oxidation gave 1,1′-(diselenodiethylene)bis(2-thiourea) (X) whose



X

infrared spectrum was very similar to that of its sulfur analog. The ring-opening reaction, in this instance, proceeded satisfactorily only in aqueous solution. The use of ethanol or aqueous ethanol gave a gummy product which resisted all attempts to crystallize it.

Compounds related to I which were unaffected by hydrogen sulfide are 2-aminothiazole, 2-aminobenzothiazole, 2-acetamido-2-thiazoline, 1-phenyl-3-(2-thiazolin-2-yl)urea, 1-phenyl-3-(2-thiazolin-2-yl)-2-thiourea, and 2-anilino-3-phenylthiazolidine.

The derivatives of I in which the 2-amino group is substituted were made most conveniently by the method of McKay, *et al.*,[9] from 2-(methylthio)-2-thiazoline and the appropriate amine. The usual synthesis[10] of 2-methylamino-2-thiazoline by the reaction of methylisothiocyanate and 2-bromoethylamine gives the product in a low, variable yield; however, by a modification of the McKay method 2-methylamino-2-thiazoline was obtained more conveniently in about 50% yield. The 3-methyl derivative of I can be made readily by the reaction[5] of methyl iodide on I, but use of other alkyl halides did not yield 3-substituted derivatives satisfactorily. 3-Decyl-2-iminothiazolidine and I were obtained in high yield by the reaction[11] of cyanide on the sodium salts of 2-(decylamino)ethanethiosulfuric acid and 2-aminoethanethiosulfuric acid, respectively.

Experimental Section[12]

The Reaction of 2-Amino-2-thiazolines with Hydrogen Sulfide.—Into an ice-cooled solution of 0.40 g (0.01 mole) of sodium hydroxide in 20 ml of water to which had been added 0.01 mole of a 2-amino-2-thiazoline hydrobromide or hydrochloride was bubbled hydrogen sulfide through a fritted gas dispersion tube for 0.5–1 hr. Ethanol was added to assist solution of the less soluble thiazolines. The flask containing the H_2S-saturated solution was kept at room temperature for approximately 1–2 days. Nitrogen or air was then bubbled into the solution which was heated on a steam bath, to dispel the excess hydrogen sulfide.

(5) K. K. Kuz'mina, N. G. Ostroumova, Yu. N. Markova, and M. N. Shchukina, *Zh. Obshch. Khim.*, **32**, 3215 (1962).

(6) T. P. Johnston, C. R. Stringfellow, and A. Gallagher, *J. Org. Chem.*, **30**, 2073 (1965).

(7) G. H. Buchanan, *Ind. Eng. Chem.*, **15**, 637 (1923).

(8) K. A. Jensen and P. H. Nielsen, *Acta Chem. Scand.*, **20**, 597 (1966).

(9) A. F. McKay, D. J. Whittingham, and M. E. Kreling, *J. Am. Chem. Soc.*, **80**, 3339 (1958).

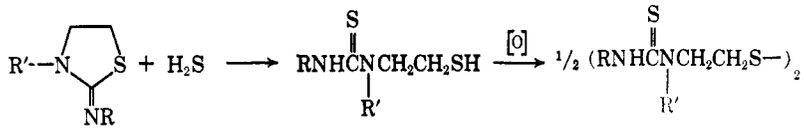
(10) S. Gabriel, *Ber.*, **22**, 1139 (1889).

(11) D. L. Klayman and G. W. A. Milne, *J. Org. Chem.*, **31**, 2349 (1966).

(12) Melting points were determined on a Fisher-Johns melting point apparatus and are uncorrected. Microanalyses were performed by Mr. J. F. Alicino, Metuchen, N. J. Infrared spectra were determined on a Beckman IR-5 spectrophotometer as KBr pellets.

TABLE I

1,1′-(DITHIODIETHYLENE)BIS(2-THIOUREAS)



(RNHCNR′CH₂CH₂S–)₂ R	R′	Mp, °C	Yield, %	Recrystn solvent	Molecular formula	Calcd, % C	H	N	S	Found, % C	H	N	S
H	H	139–140	83	H_2O	$C_6H_{14}N_4S_4$	26.64	5.21	20.72	47.42	26.83	5.27	20.66	47.66
H	CH_3	155–157	56	MeOH	$C_8H_{18}N_4S_4$[a]	32.19	6.07	18.77	42.96	31.99	6.33	18.90	42.81
H	$C_{10}H_{21}$	77–78	58	CH_3CN	$C_{26}H_{54}N_4S_4$[b]	56.67	9.88	10.17	23.28	56.86	10.04	9.91	23.20
CH_3	H	85–87	70	MeOH–EtOAc	$C_8H_{18}N_4S_4$[c]	32.19	6.07	18.77	42.96	32.32	6.15	18.90	42.60
C_6H_5	H	148–150	68	EtOH	$C_{18}H_{22}N_4S_4$[d]	51.15	5.24	13.26	30.35	51.16	5.52	13.31	30.33
$C_6H_5CH_2$	H	142–144	68	EtOH	$C_{20}H_{26}N_4S_4$[e]	53.29	5.82	12.43	28.46	53.00	6.05	12.41	28.22
$C_{10}H_{21}$	H	120–121	80	EtOH	$C_{26}H_{54}N_4S_4$[f]	56.67	9.88	10.17	23.28	56.64	10.24	10.37	22.95
NH_2	H	163–165	82	CH_3CN	$C_6H_{16}N_8S_4$[g]	23.98	5.37	27.97	42.63	24.19	5.34	28.37	42.46

[a] Registry no.: 15267-13-7; [b] 15267-14-8; [c] 15267-15-9; [d] 15267-16-0; [e] 15267-17-1; [f] 15267-18-2; [g] 15267-12-6.

This was continued until aliquots treated with lead acetate solution gave a yellow precipitate consisting of the lead mercaptide of the 1-(mercaptoethyl)-2-thiourea. Lead sulfide imparted a gray or black color to the precipitate. The pH of the solution, originally 10–11, had decreased to 6–8. (A higher pH indicates incomplete ring opening.) The solution was treated with 5% hydrogen peroxide added dropwise, until the nitroprusside test became negative. The solution was evaporated to near dryness under reduced pressure and cooled to induce crystallization of the 1,1′-(dithiodiethylene)bis(2-thiourea). The compounds prepared by this method are listed in Table I.

Conversion of the hydriodide salt of 2-imino-3-methylthiazolidine to the free base and removal of the iodide in advance of the hydrogen sulfide treatment simplified the purification of the product.

1-(Mercaptoethyl)-2-thiourea (V).—Hydrogen sulfide was passed into a cooled solution of 5.10 g (0.05 mole) of I in 100 ml of ethanol for 4 hr and the solution was permitted to stand overnight. Nitrogen was then bubbled into the heated solution to dispel the hydrogen sulfide and the solvent was removed under reduced pressure. The residual oil was triturated with a few drops of ether and cooled causing crystallization of 4.61 g (68%) of the product, mp 79–83°. The product was kept as much as possible in an atmosphere of nitrogen to minimize air oxidation. Recrystallization of the material from water gave 1-(mercaptoethyl)-2-thiourea (V): mp 82–84°; infrared 4.03 (SH), thiourea bands[8] 6.14 (A), 6.50 (B), 7.80 (C), 9.00 (D), 11.38 (E), 13.83 (F), 13.15 μ (G).

Anal. Calcd for $C_3H_8N_2S_2$: C, 26.44; H, 5.91; N, 20.56; S, 47.07; –SH, 24.3. Found: C, 26.64; H, 6.15; N, 20.27; S, 47.17; –SH, 24.9.

Reaction of I with Hydrogen Sulfide in Ethanol Solution.—Hydrogen sulfide was slowly bubbled for 2 hr into a cooled solution of 2.55 g (0.025 mole) of I in 40 ml of absolute ethanol and the solution was allowed to stand overnight. The excess hydrogen sulfide was dispelled from the heated solution which was then diluted with 40 ml of water. Air was passed into the solution at room temperature until a negative nitroprusside test was obtained. Two crops of VI were collected, 2.40 g (71%), mp 135–137°. Further recrystallization from water raised the melting point to 139–140°.

The filtrate obtained after the removal of the VI was evaporated to dryness and the residue was extracted with hot chloroform. The combined extracts were taken to dryness giving an oil which slowly crystallized. The 2-thiazolidinethione (VIII), was recrystallized from ethanol to yield 0.01 g (0.3%) of the product, mp 107° (lit.[10] 106–107°). The infrared spectrum of VIII showed a characteristic peak at 6.60 μ (N—C=S) and was identical with that of an authentic sample.

Reaction of 2-Amino-5,6-dihydro-4H-1,3-thiazine (IV) with Hydrogen Sulfide. A. In Aqueous Solution.—Hydrogen sulfide was slowly bubbled into a cooled solution of 1.5 g (0.01 mole) of IV hydrochloride[3,11] and 0.4 g (0.01 mole) of sodium hydroxide in 25 ml of water for 1 hr and the solution was allowed to stand overnight. The excess hydrogen sulfide was dispelled and the product was oxidized with 5% hydrogen peroxide. The solution was evaporated to near dryness and cooled giving the crystalline disulfide. The product was recrystallized from water to give 0.87 g (58%) of 1,1′-[dithiobis(trimethylene)]bis(2-thiourea) (VII), mp 143–145°.

Anal. Calcd for $C_8H_{18}N_4S_4$: C, 32.19; H, 6.07; N, 18.77; S, 42.97. Found: C, 32.51; H, 6.11; N, 18.70; S, 42.70.

B. In Ethanol Solution.—Compound IV hydrochloride (1.52 g, 0.01 mole) was dissolved in 25 ml of absolute ethanol containing 0.40 g (0.01 mole) of sodium hydroxide and the sodium chloride which separated was removed by filtration. Hydrogen sulfide was slowly bubbled into the ice-cooled filtrate for 2 hr and the solution was allowed to stand overnight. The products were worked up in the manner described above for the reaction of I with hydrogen sulfide in ethanol. There separated from the ethanol solution 0.82 g (55%) of VII, mp 133–140°. Recrystallization from water raised the melting point to 143–145°.

Evaporation of the mother liquors and extraction of the residue with hot chloroform gave 0.11 g (8%) of tetrahydro-1,3-thiazine-2-thione (IX) which melted at 133–134° (lit.[13] mp 132°) after recrystallization from ethanol. The infrared spectrum of IX showed a characteristic peak at 6.50 μ (N—C=S) and was identical with that of a sample made by the reaction of 3-bromopropylamine with carbon disulfide according to the method of Gabriel.[13]

Anal. Calcd for $C_4H_7NS_2$: C, 36.06; H, 5.30; N, 10.52; S, 48.13. Found: C, 36.14; H, 5.35; N, 10.75; S, 47.96.

1,1′-(Diselenodiethylene)bis(2-thiourea) (X).—A cooled solution of 1.74 g (0.0076 mole) of 2-amino-2-selenazoline hydrobromide[14] and 0.30 g (0.0075 mole) of sodium hydroxide in 50 ml of water was treated with hydrogen sulfide for 2 hr and permitted to stand at room temperature for 3 days. The yellow crystals which formed were collected giving 0.76 g (55%) of X. The compound after recrystallization from methanol melted at 128–130°.

Anal. Calcd for $C_6H_{14}N_4S_2Se_2$: C, 19.78; H, 3.87; N, 15.38; S, 17.61; Se, 43.35. Found: C, 19.75; H, 4.21; N, 15.37; S, 17.66; Se, 43.09.

Improved Synthesis of 2-Amino-2-thiazoline (I).[15]—Sodium hydroxide (8 g, 0.2 mole), 31.4 g (0.2 mole) of 2-aminoethanethiosulfuric acid, and 10.8 g (0.22 mole) of sodium cyanide were successively dissolved in 250 ml of water. The colorless solution was periodically swirled at room temperature for 2 hr and was then evaporated to dryness under reduced pressure. The white residue was extracted with three 125 ml portions of boiling chloroform and the combined extracts were evaporated to dryness. The viscous residual oil crystallized very readily on cooling and scratching to give 18.5 g (91%) of 2-amino-2-thiazoline, mp 78–80°. Recrystallization of the material from either benzene or ether gave I as long needles, mp 80–82°.

3-Decyl-2-iminothiazolidine Hydrochloride.—To a solution of 14.8 g (0.05 mole) of 2-(decylamino)ethanethiosulfuric acid[16] in

(13) S. Gabriel and W. E. Lauer, *Ber.*, **23**, 87 (1890).

(14) D. L. Klayman, *J. Org. Chem.*, **30**, 2454 (1965); S. H. Chu and H. G. Mautner, *ibid.*, **27**, 2899 (1962); W. Baringer, *Ber.*, **23**, 1003 (1890).

(15) Based on a synthesis reported earlier; *cf.* ref 11.

(16) D. L. Klayman and W. F. Gilmore, *J. Med. Chem.*, **7**, 823 (1964).

100 ml of methanol was added with stirring 2.0 g (0.05 mole) of sodium hydroxide in 100 ml of methanol and 2.4 g (0.055 mole) of sodium cyanide in 100 ml of methanol. Sodium sulfite precipitated almost instantaneously from the mixture which was then permitted to stand overnight. The sodium sulfite was filtered from the reaction mixture and the filtrate was evaporated to dryness *in vacuo* giving a heavy oil. The product was treated in a benzene solution with anhydrous hydrogen chloride and the solvent was evaporated. The resulting semicrystalline mass was treated with ether and recrystallized from 2-propanol–ether to give 9.78 g (70%) of 3-decyl-2-iminothiazolidine hydrochloride, mp 105–107°.

Anal. Calcd for $C_{13}H_{27}ClN_2S$: C, 55.98; H, 9.76; N, 10.04; S, 11.50. Found: C, 56.08; H, 9.72; N, 9.73; S, 11.72.

2-Methylamino-2-thiazoline.—To a solution of 104.4 g (0.4 mole) of 2-(methylthio)-2-thiazoline hydriodide in 800 ml of ethanol was added 27.0 g (0.4 mole) of methylamine hydrochloride and 16.0 g (0.4 mole) of sodium hydroxide in 80 ml of water. The reaction mixture was heated at reflux for 16 hr. After cooling the mixture to room temperature, a solution of 16.0 g (0.4 mole) of sodium hydroxide in 80 ml water was added. The resultant solution was heated on a steam bath to remove the methyl mercaptan formed in the reaction and the solution was then evaporated to dryness *in vacuo*. The residue was extracted with five 200-ml portions of boiling hexane and the hexane was cooled to yield 24.6 g (53%) of 2-methylamino-2-thiazoline as colorless needles. The product after recrystallization from hexane melted at 88.5–90° (lit.[10] mp 90°).

2-Decylamino-2-thiazoline.—A solution of 13.0 g (0.05 mole) of 2-(methylthio)-2-thiazoline hydriodide and 7.8 g (0.05 mole) of decylamine in 125 ml of ethanol was heated at reflux for 17 hr and cooled to room temperature. Sodium hydroxide (2.0 g, 0.05 mole) was added and the resultant solution was evaporated to dryness *in vacuo*. The residue was extracted with three 250-ml portions of boiling chloroform and the combined chloroform extracts were dried over anhydrous magnesium sulfate and evaporated to dryness *in vacuo* giving an oil which crystallized on cooling. The 2-decylamino-2-thiazoline, 11.8 g (95%), was recrystallized from acetonitrile, mp 60–62°.

Anal. Calcd for $C_{13}H_{26}N_2S$: C, 64.40; H, 10.81; N, 11.55; S, 13.23. Found: C, 64.55; H, 11.04; N, 11.53; S, 13.11.

Registry No.—I, 1779-81-3; 2-amino-2-selenazoline, 15267-04-6; H_2S, 7783-06-4; V, 15267-06-8; VI, 15267-03-5; VII, 15267-07-9; X, 15267-08-0; 3-decyl-2-iminothiazolidine hydrochloride, 15267-09-1; 2-methylamino-2-thiazoline, 10416-51-0; 2-decylamino-2-thiazoline, 15267-11-5.

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Synthesis of 1H-Aziridine-2-carboxanilides

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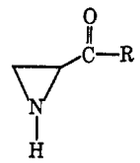
In the course of some other studies we required a facile synthesis of a series of 1H-aziridine-2-carboxanilides (**1c**). The problem of synthesis of aziridines[1] having the gross structure **1** is complicated by several factors. Most of the versatile 1H-aziridine syntheses involve as a first step the initial addition of some electrophile to an olefin, *e.g.*, iodoisocyanate,[2] nitrosyl



1a, R = alkyl, aryl
b, R = O-alkyl
c, R = N-alkyl
aryl

chloride,[3] and carbethoxynitrene.[4] However, the olefin precursor of **1** is an electrophile itself and reaction with the above-mentioned reagents does not occur.[5] There are indeed three known syntheses of compounds such as **1**: (a) reaction of a 2,3-dibromo ester with liquid ammonia,[6] (b) Michael addition of O-methylhydroxylamine followed by base,[7] and (c) reaction of an iodine–ammonia mixture with an unsaturated ketone.[8] Unfortunately, each reaction has severe limitations. Method a works only with liquid esters soluble in liquid ammonia.[5] Sequence b is hampered by the high cost, volatility, toxicity, and weak nucleophilicity of the reagent. Method c is successful only with very electrophilic olefins, *e.g.*, chalcones.[5,8] None of these procedures has been capable of generating aziridine-2-carboxanilides (**1c**).[5] We have devised a synthesis of these compounds that is related to an azirine synthesis.[9]

Addition of 1,1-dimethylhydrazine to N-isopropylacrylanilide (**2a**) occurs quantitatively (see Scheme I). Quaternization of this hydrazine **3a** with methyl iodide is quite facile producing **4a**. When methiodide **4a** is refluxed with sodium methoxide in ethanol, trimethylamine is evolved and aziridine **1c** is generated in 57% yield. When the sequence is applied to **2b** the corresponding aziridine is formed in 27% over-all yield.

We feel that this aziridine synthesis fully complements existing procedures and will be quite useful when older methods fail. The full scope of the reaction has yet to be realized.

Experimental Section[10]

N-Phenyl-N-isopropylacrylamide (2a).—To 73 g (0.81 mole) of acryloyl chloride in 1.5 l. of ether cooled in a Dry Ice–acetone bath was added slowly with stirring 135 g (1.62 mole) of N-isopropylaniline. The mixture was warmed to 25° and filtered. The filtrate was concentrated an triturated with pentane to induce crystallization. Recrystallization of the product from pentane gave 150 g (98%) of white needles, mp 33–34°. The nmr spectrum showed absorption at δ 1.1 (6 H doublet, isopropyl), 4.9 (1 H multiplet, isopropyl), 5.2–6.4 (3 H, ABX multiplet, olefinic), and 7.2 (5 H aromatic multiplet).

Anal. Calcd for $C_{12}H_{15}NO$: C, 76.25; H, 7.99. Found: C, 76.15; H, 7.84.

(1) For a general survey of aziridine syntheses, see P. A. Fanta in "Heterocyclic Compounds," Vol. 19, A. Weissberger, Ed., Interscience Publishers, Inc., New York, N. Y., 1965, p 524.

(2) A. Hassner and C. Heathcock, *Tetrahedron*, **20**, 1037 (1963).

(3) G. L. Closs and S. J. Brois, *J. Am. Chem. Soc.*, **82**, 6068 (1960).

(4) W. Lwowski and T. W. Mattingly, Jr., *ibid.*, **87**, 1947 (1965).

(5) Unpublished work from these laboratories.

(6) British Patent No. 847,205 (to F. Hoffman-La Roche and Co.); *Chem. Abstr.*, **55**, 7433e (1961).

(7) A. H. Blatt, *J. Am. Chem. Soc.*, **61**, 3494 (1939). This reaction was rediscovered by N. H. Cromwell and H. Hoeksema [*ibid.*, **71**, 708 (1949)].

(8) P. L. Southwick and D. R. Christman, *ibid.*, **74**, 1886 (1952). We have applied this reaction to many substituted chalcones with excellent results.

(9) (a) R. F. Parcell, *Chem. Ind.* (London), 1936 (1963). (b) P. A. S. Smith and E. E. Most, Jr., *J. Org. Chem.*, **22**, 358 (1957). (c) D. F. Morrow, M. E. Butler, and E. C. Y. Huang, *ibid.*, **30**, 579 (1965).

(10) Melting points are corrected; boiling points are uncorrected. The nmr spectra were recorded on a Varian A-60 spectrometer using deuteriochloroform as solvent and tetramethylsilane as an internal standard. Chemical shifts are reported in parts per million downfield from the standard. Magnesium sulfate was used for drying.