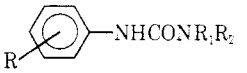
TABLE I
PHENYLSEMICARBAZIDES



No.	R	R_1	R_2	Recrystn solvent[a]	Mp, °C	Formula	Carbon, % Calcd	Carbon, % Found	Hydrogen, % Calcd	Hydrogen, % Found	N or other, % Calcd	N or other, % Found
1	H	H	$N(CH_3)_2$	B	111.5–112[b]	$C_9H_{13}N_3O$	60.31	60.40	7.31	7.27		
2	H	CH_3	NH_2	M, D, A	90–92.5[c]	$C_8H_{11}N_3O$						
3	H	H	c-$N(CH_2)_6$	A, B, M	102.5–103	$C_{13}H_{19}N_3O$	66.92	66.70	8.21	8.25		
4	2-Cl	H	$N(CH_3)_2$	M, L	88.5–89.5[d]	$C_9H_{12}ClN_3O$	50.59	50.77	5.66	5.77		
5	2-Cl	CH_3	NH_2	M, L	100–101	$C_8H_{10}ClN_3O$	48.13	48.36	5.05	5.14	17.76[e]	17.39[e]
6	3-Cl	H	$N(CH_3)_2$	L, M	98–99.5[f]	$C_9H_{12}ClN_3O$						
7	3-Cl	CH_3	NH_2	M, A, C	158–160.5	$C_8H_{10}ClN_3O$	48.12	48.36	5.05	5.15	17.77[e]	18.06[e]
8	4-Cl	H	$N(CH_3)_2$	L, A	150–151.5[g]	$C_9H_{12}ClN_3O$	50.59	50.22	5.66	5.53	16.60[e]	16.25[e]
9	4-Cl	H	c-$N(CH_2)_6$	C	150.5–152	$C_{13}H_{18}ClN_3O$	58.31	58.14	6.78	6.51		
10	3,4-Cl_2	H	$N(CH_3)_2$	B	132–133.5	$C_9H_{11}Cl_2N_3O$	43.56	43.58	4.47	4.59		
11	3,4-Cl_2	CH_3	NH_2	M, A, D, L	137.5–139	$C_8H_9Cl_2N_3O$	41.04	40.87	3.88	3.83	30.29[e]	30.06[e]
12	3,4-Cl_2	H	c-$N(CH_2)_6$	C, B	155–156	$C_{13}H_{17}Cl_2N_3O$	51.66	51.70	5.67	5.61		
13	4-F	H	$N(CH_3)_2$	A, L, B	121–122	$C_9H_{12}FN_3O$	51.81	51.95	6.13	6.09		
14	4-Br	H	$N(CH_3)_2$	L, M	153.5–154.5	$C_9H_{12}BrN_3O$	41.88	41.72	4.69	4.67	30.96[f]	30.15[h]
15	4-Br	CH_3	NH_2	A, M	153–155	$C_8H_{10}BrN_3O$	39.36	39.56	4.13	4.14		
16	2-CH_3	H	$N(CH_3)_2$	M	142–143	$C_{10}H_{15}N_3O$	62.15	62.09	7.82	7.75	21.75	22.02
17	2-CH_3	CH_3	NH_2	M	101.5–102.5	$C_9H_{13}N_3O$	60.31	59.21	7.31	7.10	23.45	23.99
18	3-CH_3	H	$N(CH_3)_2$	L, M	78–79	$C_{10}H_{15}N_3O$	62.15	62.35	7.82	7.99	21.75	21.60
19	3-CH_3	CH_3	NH_2	D, L	91–92.5	$C_9H_{13}N_3O$	60.31	60.10	7.31	7.18	23.45	23.20
20	4-CH_3	H	$N(CH_3)_2$	L, M, A	136–137	$C_{10}H_{15}N_3O$	62.15	62.01	7.82	7.78	21.75	21.49
21	4-CH_3	CH_3	NH_2	L	141–143.5	$C_9H_{13}N_3O$	60.31	60.68	7.31	7.21	23.45	23.22
22	2-NO_2	H	$N(CH_3)_2$	M	143–145	$C_9H_{12}N_4O_3$	48.21	48.45	5.40	5.54	24.99	25.15
23	2-NO_2	CH_3	NH_2	M, A, C	148.5–149	$C_8H_{10}N_4O_3$	45.71	45.75	4.80	4.95	26.66	26.80
24	3-NO_2	H	$N(CH_3)_2$	M, L	142.5–143.5	$C_9H_{12}N_4O_3$	48.21	47.97	5.40	5.34	24.99	24.80
25	3-NO_2	CH_3	NH_2	M, A, C	150–152	$C_8H_{10}N_4O_3$	45.71	45.85	4.80	4.91	26.66	26.90
26	4-NO_2	H	$N(CH_3)_2$	M, A	206–206.5	$C_9H_{12}N_4O_3$	48.21	47.98	5.40	5.43	24.99	24.80
27	4-NO_2	CH_3	NH_2	M	195–196.5	$C_8H_{10}N_4O_3$	45.71	45.92	4.80	4.80	26.66	26.40
28	4-OCH_3	H	$N(CH_3)_2$	L, D	123–124	$C_{10}H_{15}N_3O_2$	57.40	57.31	7.23	7.33	20.08	19.85
29	4-OCH_3	CH_3	NH_2	L	105–106	$C_9H_{13}N_3O_2$	55.37	55.55	6.71	6.69	21.53	20.99

[a] Solvents: A = EtOAc–ligroin, B = Me_2CO–ligroin, C = $CHCl_3$–ligroin, D = Et_2O–MeOH–ligroin, E = aqueous EtOH, L = Et_2O–ligroin, M = aqueous MeOH. [b] R. S. Levy [*Mem. Poudres*, **40**, 429 (1958); *Chem. Abstr.*, **55**, 19839 (1961)] reported mp 108°. [c] M. Busch, E. Opfermann, and H. Walther [*Chem. Ber.*, **37**, 2324 (1904)] reported mp 93–94°. [d] Lit.[b] mp 96°. [e] Cl analysis. [f] Lit.[b] mp 99°. [g] Lit.[b] mp 138°. [h] Br analysis.

Untreated controls, methanol-treated controls, and standards treated with the herbicide 3-(3,4-dichlorophenyl)-1,1-dimethylurea (diuron) or 2-chloro-4-ethylamino-6-isopropylamino-*s*-triazine (atrazine) at 10 lb/acre were also included. Plants treated with diuron or atrazine showed phytotoxic symptoms within 5 days. After 7 weeks all plants were dead in the diuron-treated flats, and only *Zea mays* survived in the atrazine-treated flats. The plants in flats treated with compounds in Table I showed no symptoms of phytotoxicity during this period.

Experimental Section[5]

4-Phenylsemicarbazides.—The appropriate phenyl isocyanate was dissolved in 5 vol of dry ethyl ether if liquid, or if a solid, in 10 vol of toluene at 45° and added slowly to 1.1 equiv of the appropriate alkylhydrazine in 30 vol of dry Et_2O at room temperature. The crude product usually precipitated in approximately quantitative yield within a few minutes, except 2-chlorophenyl and 2-tolyl analogs, which required concentration of solvent. The crude product was filtered off and recrystallized as indicated in Table I.

Acknowledgments.—The author is indebted to H. J. Thome, E. I. du Pont de Nemours and Co., Wilmington, Del., for 3,4-dichlorophenyl isocyanate, to FMC Corp., Princeton, N. J., for N-aminohexamethylenimine, and to A. W. Burgess and P. K. Cramer for valuable technical assistance.

(5) Melting points were determined by means of a Kofler micro hot stage and are corrected. The elemental analyses were performed by Drs. G. Weiler and F. Strauss, Microanalytical Laboratory, Oxford, England.

5-Aryl-1,5-dihydro-2H-1,4-benzodiazepin-2-ones[1a]

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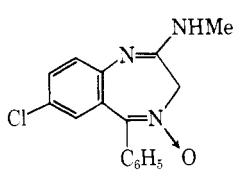
Considerable therapeutic importance attaches to several representatives of the 1,4-benzodiazepine ring system.[1b] Four such compounds (chlordiazepoxide, I; diazepam, II; oxazepam, III; and nitrazepam, IV) are employed clinically for their effects on the central nervous system, and many others have undergone testing. The benzodiazepines thus resemble the phenothiazine tranquilizers in the breadth of structural variation that is possible without loss of pharmacological activity.

All of the marketed compounds have a >C=N– system between positions 4 and 5 (I N-oxide), but published reports indicate that saturation of this bond does not destroy activity.[1b] We wished to examine the effects of shifting the unsaturation from the 4,5 to the 3,4 positions and have developed methods for preparing the desired 1,5-dihydro-2H-1,4-benzodiazepin-2-ones. The chemical reactions of these products have been

(1) (a) Presented in part at the 152nd National Meeting of the American Chemical Society, New York, N. Y., Sept 1966; (b) S. J. Childress and M. I. Gluckman, *J. Pharm. Sci.*, **53**, 577 (1964).

studied, and in one sequence a novel preparation of oxazepam has been achieved.

Proctor and others[2-5] have studied the base-catalyzed elimination of the sulfinate anion from variously substituted sulfonamides to afford imines. For example, 5,6-dihydro-5-*p*-tolylsulfonyl-7H-dibenz[*b*,*d*]-azepin-7-one (V) with sodium ethoxide at room temperature gave 7H-dibenz[*b*,*d*]azepin-7-one (VI). In order to apply this method to the preparation of a 1,5-dihydro-2H-1,4-benzodiazepin-2-one, it was necessary to prepare a 4-*p*-tolylsulfonyl-1,3,4,5-tetrahydro-



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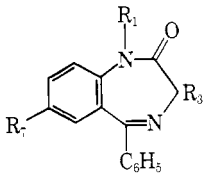
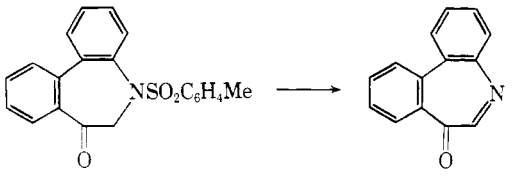


	R_1	R_3	R_7
II	Me	H	Cl
III	H	OH	Cl
IV	H	H	NO_2



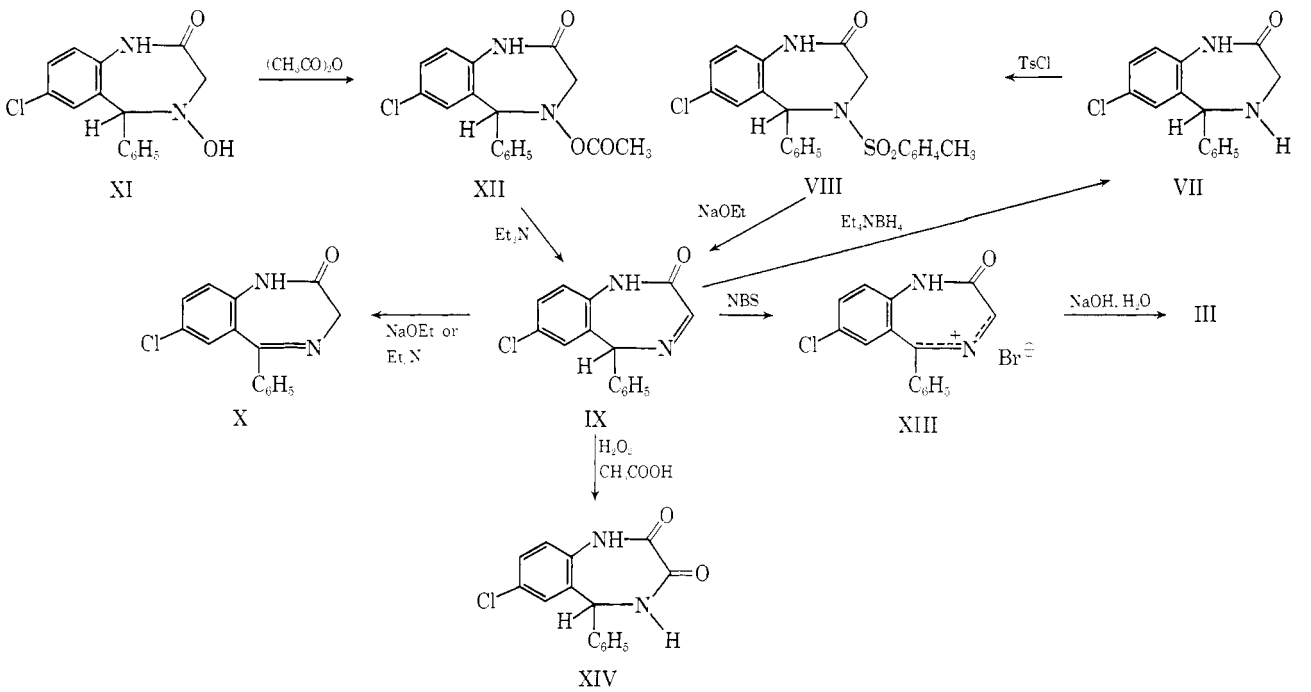
V VI

2H-1,4-benzodiazepin-2-one (VIII) which was easily accomplished from the readily available VII (Chart I). Although the activation of the 3-methylene group of VIII which is adjacent to a lactam carbonyl group is less than that of Proctor's ketone V, conditions similar to his brought about the elimination of *p*-toluenesulfinic acid to afford a mixture of compounds from which the desired IX as well as the already known compound X[6,7] was isolated.

The nmr spectrum of IX was consistent with the assigned structure. Two doublets resulting from allylic coupling between the 3-proton and the 5-proton occur at δ 5.78 and 6.58 (J = 2 cps). In contrast, the isomeric X shows a singlet at δ 4.22 for its 3-protons. Recovery of the original starting material VII by reduction of IX with tetraethylammonium borohydride demonstrated the preservation of the 1,4-benzodiazepine ring. Compound IX was isomerized to X by vigorous treatment with sodium ethoxide which raises a question as to the mechanism by which X is formed in the reaction.

Because of the undesirable presence of X in the reaction product and its possible origin in the conversion of IX into X under the conditions of the reaction, another milder method was sought for the preparation of IX. The selection of a better leaving group than sulfinate was a possible improvement. The elimination of an anion such as acetate from the appropriately substituted hydroxylamine seemed a likely prospect, since the prerequisite generation of an adjacent carbanion would be analogous to that occurring in the foregoing sulfinate elimination. Accordingly, the available 7-chloro-1,3,-4,5-tetrahydro-4-hydroxy-5-phenyl-2H-1,4-benzodiazepin-2-one (XI)[6] was acetylated to give the 4-acetoxy compound XII which was treated with triethylamine to bring about the elimination of acetate. Triethylamine was chosen over sodium ethoxide in order to decrease the possibility of ester cleavage. From XII, both IX and X were again obtained in a ratio of 8:1. It was possible to isomerize IX into X by heating with triethylamine, thus leaving unclear the course by which X arose in the reaction mixture.

CHART I



(2) G. R. Proctor, *Chem. Ind.* (London), 408 (1960).
(3) A. V. Robertson, J. E. Francis, and B. Witkop, *J. Am. Chem. Soc.*, **84**, 1709 (1962).
(4) A. H. Jackson, G. W. Kenner, and W. G. Terry, *Tetrahedron Letters*, 921 (1962).
(5) E. Negishi and A. R. Day, *J. Org. Chem.*, **30**, 43 (1965).
(6) L. H. Sternbach and E. Reeder, *ibid.*, **26**, 4936 (1961).
(7) S. C. Bell, T. S. Sulkowski, C. Gochman, and S. J. Childress, *ibid.*, **27** 562 (1962).

3,7-Dichloro-1,3-dihydro-5-phenyl-2H-1,4-benzodiazepin-2-one hydrolyzes with aqueous base to give the corresponding 3-hydroxy compound (oxazepam) III. Our attempts to halogenate the 3 position of X and thus provide a useful intermediate in the synthesis of III had failed. Neither bromine nor N-bromosuccinimide affected X, and the use of chlorine in acid solution was similarly ineffective.[8] Bromination of IX with N-bromosuccinimide, however, gave a bromo derivative (XIII) whose infrared spectrum resembles that of the 3-chloro derivative of X.[9] Hydrolysis of XIII in aqueous base gave III. The 3,4,5 positions of IX constitute an allylic triad and either the bromination or the nucleophilic displacement of the bromo substituent of XIII is envisioned as involving an allylic rearrangement. Direct oxidation of IX did not involve an allylic change, and the previously described XIV[9] was obtained.

Compound IX was studied in the usual screening tests applicable to benzodiazepines.[1b] The general profile of tests showed IX to be less potent than its isomer X. For example, in the key antipentylenetetrazol test in mice IX had ED_{50} 21 mg/kg, whereas X had ED_{50} 0.9 mg/kg. In the 1,3-dihydro-2-one series, potency is greatly increased by introduction of an electronegative group in the *ortho* position of the 5-phenyl substituent. Accordingly, the 5-(*o*-chlorophenyl) analog of IX was prepared and tested, but it was much less potent than IX.

Experimental Section

Melting points were determined in an oil bath and are uncorrected. Infrared spectra were taken in KBr. Nmr spectra were recorded in DMSO-*d* with TMS as an internal standard.

7-Chloro-1,3,4,5-tetrahydro-5-phenyl-4-(*p*-tolylsulfonyl)-2H-1,4-benzodiazepin-2-one (VIII).—To a mixture of 3.0 g of VII[6] in 20 ml of pyridine was added 3.5 g of *p*-toluenesulfonyl chloride. The reaction mixture was heated on the steam bath for 15 min and diluted with H_2O. The resultant precipitate was collected and washed with H_2O and with EtOH. There was obtained 4.6 g of VIII, mp 246–248° (from EtOH).

Anal. Calcd for $C_{22}H_{19}ClN_2O_3S$: C, 61.89; H, 4.49. Found: C, 61.77; H, 4.55.

4-Acetoxy-7-chloro-1,3,4,5-tetrahydro-5-phenyl-2H-1,4-benzodiazepin-2-one (XII).—A mixture of 3 g of XI[6] and 50 ml of Ac_2O was heated on the steam bath for 10 min. A clear solution was obtained that deposited, upon cooling, 1.3 g of XII, mp 193–195°.

Anal. Calcd for $C_{17}H_{13}ClN_2O_3$: C, 61.72; H, 4.57; Cl, 10.72; N, 8.47. Found: C, 61.81; H, 4.62; Cl, 10.6; N, 8.74.

7-Chloro-5-(*o*-chlorophenyl)-1,3,4,5-tetrahydro-4-hydroxy-2H-1,4-benzodiazepin-2-one, mp 203–205° (from MeCN), was prepared by the method Sternbach and Reeder[6] employed for XI.

Anal. Calcd for $C_{15}H_{12}Cl_2N_2O_2$: C, 55.74; H, 3.74; Cl, 21.94; N, 8.67. Found: C, 55.70; H, 3.76; Cl, 21.4; N, 8.43.

4-Acetoxy-7-chloro-5-(*o*-chlorophenyl)-1,3,4,5-tetrahydro-2H-1,4-benzodiazepin-2-one, mp 193–195°, was prepared in the same way as XII.

Anal. Calcd for $C_{17}H_{14}Cl_2N_2O_3$: C, 55.90; H, 3.86; Cl, 19.4; N, 7.67. Found: C, 55.61; H, 3.83; Cl, 19.1; N, 7.50.

7-Chloro-1,5-dihydro-5-phenyl-2H-1,4-benzodiazepin-2-one (IX) *via* *p*-Toluenesulfinic Acid Elimination.—Compound VIII (427 mg, 1.0 mmole) was added to 10 ml of EtOH with which 48 mg (2.08 mg-atoms) of Na had reacted. The solution was heated at reflux for 30 min and concentrated. The residue was slurried in MeCN and filtered. The filtrate was evaporated to an oil and redissolved in $CHCl_3$. This solution was extracted with dilute HCl, H_2O, and saturated NaCl. The $CHCl_3$ extract was dried by passage through cotton and concentrated *in vacuo* to a foam. Treatment of the foam with EtOH caused 150 mg of IX to separate as needles: mp 215–217°; λ_{max}^{KBr} 5.96 μ; λ_{max}^{EtOH} 242 mμ (ϵ 9500); nmr, δ 5.78 and 6.58 (3- and 5-H, d, J = 2 cps), 7.3–7.9 (aromatic multiplet, 8 H), 11.2 (NH).

Anal. Calcd for $C_{15}H_{11}ClN_2O$: C, 66.55; H, 4.10; Cl, 13.10; N, 10.35. Found: C, 66.49; H, 4.13; Cl, 12.9; N, 10.26.

Concentration of the EtOH filtrate afforded 58 mg of colorless crystals, mp 188–198°. The impure product was predominantly 7-chloro-1,3-dihydro-5-phenyl-2H-1,4-benzodiazepin-2-one (X) by infrared comparison with authentic material.[7] The melting point was raised to 210–214° upon recrystallization from EtOH.

Compound IX *via* XII.—A mixture of 6.5 g of XII, 7 ml of Et_3N, and 260 ml of EtOH was heated under reflux for 10 min. Cooling produced 3.8 g of IX, mp 215–216°. The filtrate was concentrated *in vacuo*, and the residue was recrystallized from EtOH to afford 0.5 g of X, mp 212–214°.

7-Chloro-5-(*o*-chlorophenyl)-1,5-dihydro-2H-1,4-benzodiazepin-2-one, mp 248–250°, was prepared by the Et_3N method from 4-acetoxy-7-chloro-5-(*o*-chlorophenyl)-1,3,4,5-tetrahydro-2H-1,4-benzodiazepin-2-one.

Anal. Calcd for $C_{15}H_{10}Cl_2N_2O$: C, 59.03; H, 3.30; Cl, 23.2; N, 9.18. Found: C, 59.02; H, 3.44; Cl, 22.7; N, 9.42.

7-Chloro-1,3-dihydro-5-phenyl-2H-1,4-benzodiazepin-2-one (X). A. Isomerization of IX with Sodium Ethoxide.—Compound IX (542 mg, 2.0 mmoles) slurried in 20 ml of EtOH was treated with 3.95 ml of 0.52 *N* EtONa in EtOH. The mixture was stirred and heated at reflux for 0.5 hr. Removal of the solvent *in vacuo* afforded an oily residue which was dissolved in $CHCl_3$. The solution was extracted successively with dilute HCl, H_2O, and saturated NaCl and was dried by passage through cotton. Evaporation of the solvent and treatment of the oily residue with MeCN afforded 273 mg of unchanged starting material. The filtrate, kept at 27° for several days, deposited 49 mg of X, mp 212–214°.

B. Isomerization of IX in Triethylamine.—Compound IX (575 mg, 2.12 mmoles) was heated at reflux for 0.5 hr in 12.5 ml of Et_3N. The reaction mixture was allowed to cool to room temperature. Filtration of the mixture gave 457 mg (79.5%) of unchanged IX, mp 212–214°. Evaporation of the filtrate and treatment of the resultant oil with EtOH afforded 65 mg of X, mp 212–214°.

Reduction of IX.—To a solution of 0.4 g of tetraethylammonium borohydride in 20 ml of EtOH was added 0.4 g of IX, and the mixture was heated to 55° until the solid dissolved. The solution was cooled and diluted with H_2O. The product which separated (0.3 g) was found to be identical with authentic 7-chloro-5-phenyl-1,3,4,5-tetrahydro-2H-1,4-benzodiazepin-2-one (VII).[6]

Oxidation of IX.—To a stirred suspension of IX (500 mg, 3.61 mmoles) in 10 ml of HOAc at 27° was added 0.62 ml of 50% H_2O_2. After 45 min, the solid had dissolved, and stirring was continued for 1 hr. The white precipitate which separated after gradual addition of 40 ml of H_2O was collected and washed with H_2O. Recrystallization from aqueous methoxyethanol afforded 203 mg of XIV, mp 294–295°. The infrared spectrum of the product was identical with the spectrum of material prepared previously.[9]

7-Chloro-1,3-dihydro-3-hydroxy-5-phenyl-2H-1,4-benzodiazepin-2-one (III).—A solution of 920 mg (3.4 mmoles) of IX in 150 ml of warm C_6H_6 was treated with 656 mg (3.68 mmoles) of N-bromosuccinimide and 50 mg of dibenzoyl peroxide and was stirred for 5.25 hr at 26°. Filtration gave 300 mg of a yellow crystalline hydrobromide, mp 177–179° (λ_{max}^{KBr} 5.90 μ), which was dissolved in 1.5 ml of DMF. The solution was diluted with 4.0 ml of warm H_2O to yield 28 mg of III which after recrystallization from EtOH had mp 203–204°. The infrared spectrum was identical with that of an authentic sample.[9]

Acknowledgment.—We are grateful to Mr. Bruce Hofmann and his staff for microanalyses, to Dr. Charles Hetzel for nmr spectra, and to Mr. George L. Conklin and Mr. Carl Gochman for technical assistance.

(8) A recent patent indicates the successful halogenation of X with N-halo compounds: R. I. Fryer, E. E. Garcia, and L. H. Sternbach, South African Patent 66/7088 (1967).

(9) S. C. Bell and S. J. Childress, *J. Org. Chem.*, **27**, 1691 (1962).