The Friedel–Crafts Acetylation and Chloroacetylation of the Benzophenothiazines

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The Friedel–Crafts acetylation and chloroacetylation of 12H-benzo[*a*]phenothiazine, 12H-benzo[*b*]phenothiazine, and 7H-benzo[*c*]phenothiazine ring systems have been investigated, and the position of acetylation and chloroacetylation in the respective ring systems has been proved. In each system monoacylation in good yield occurred at single ring positions.

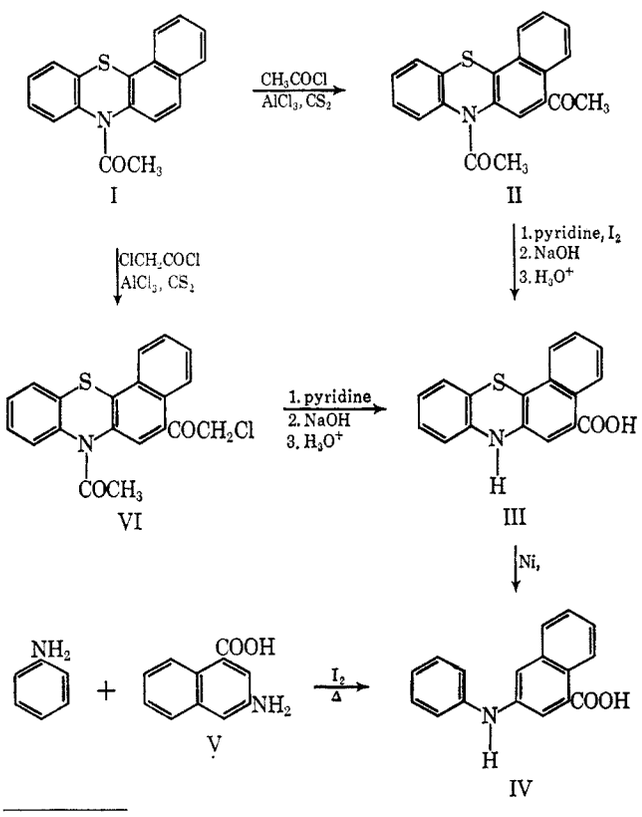
The Friedel–Crafts reaction involving phenothiazine has been investigated by Scholl and Seer[2] and by Baltzly, Harfenist, and Webb,[3] who determined the orientation in the reaction. However, the Friedel–Crafts reaction of the benzophenothiazines has received little attention. Burger and Clements[4] reported the acetylation of 7-acetylbenzo[*c*]phenothiazine but did not establish the structure of the product.

In connection with our study of the chemistry of the benzophenothiazines, we have examined the Friedel–Crafts acetylation and chloroacetylation of benzo[*a*]-, benzo[*b*]-, and benzo[*c*]phenothiazine.

Results and Discussion

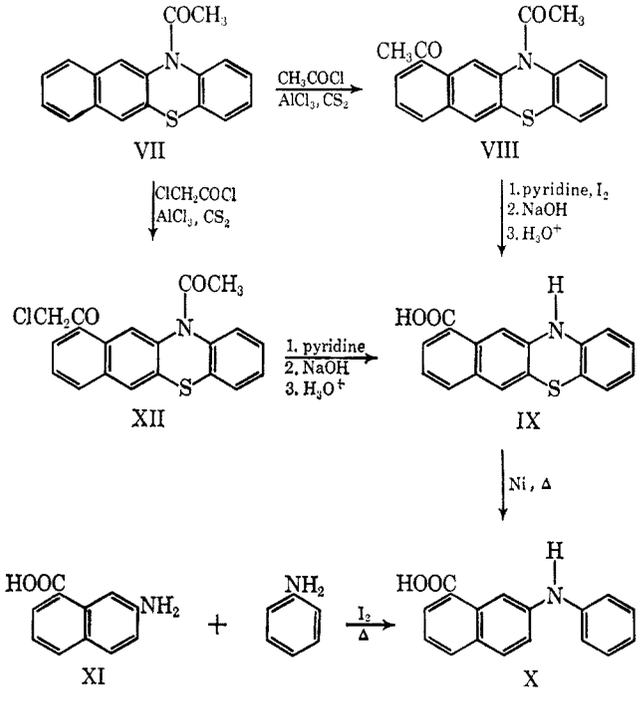
7H-Benzo[*c*]phenothiazine.—The Friedel–Crafts acetylation of 7-acetylbenzo[*c*]phenothiazine (I) occurred at the 5 position in 66% yield as indicated by the isolation of 5,7-diacetylbenzo[*c*]phenothiazine (II). The structure of the diacetyl derivative was established in the manner indicated in Scheme I. The diacetyl derivative (II) was degraded to 5-carboxy-7H-benzo[*c*]phenothiazine (III). Raney nickel desulfurization of III yielded a monocarboxylic acid which was identical with a sample of 3-(phenylamino)-1-naphthoic acid (IV), prepared by an unambiguous synthesis involving aniline and 3-amino-1-naphthoic acid (V). Similar orientation was observed in the Friedel–Crafts chloroacetylation of I, as indicated by conversion of 5-chloroacetyl-7-acetylbenzo[*c*]phenothiazine (VI) into III.

SCHEME I



12H-Benzo[*b*]phenothiazine.—The Friedel–Crafts acetylation of 12-acetylbenzo[*b*]phenothiazine (VII) occurred in 71–77% yield in the 10 position. The position of acetylation in the nucleus of 12H-benzo[*b*]-phenothiazine was established (Scheme II) by degradation of 10,12-diacetylbenzo[*b*]phenothiazine (VIII) to 10-carboxy-12H-benzo[*b*]phenothiazine (IX). Raney nickel desulfurization of IX yielded a monocarboxylic acid which was identical with a sample of 7-(phenylamino)-1-naphthoic acid (X) synthesized by the reaction of 7-amino-1-naphthoic acid (XI) with aniline in the presence of iodine.

SCHEME II

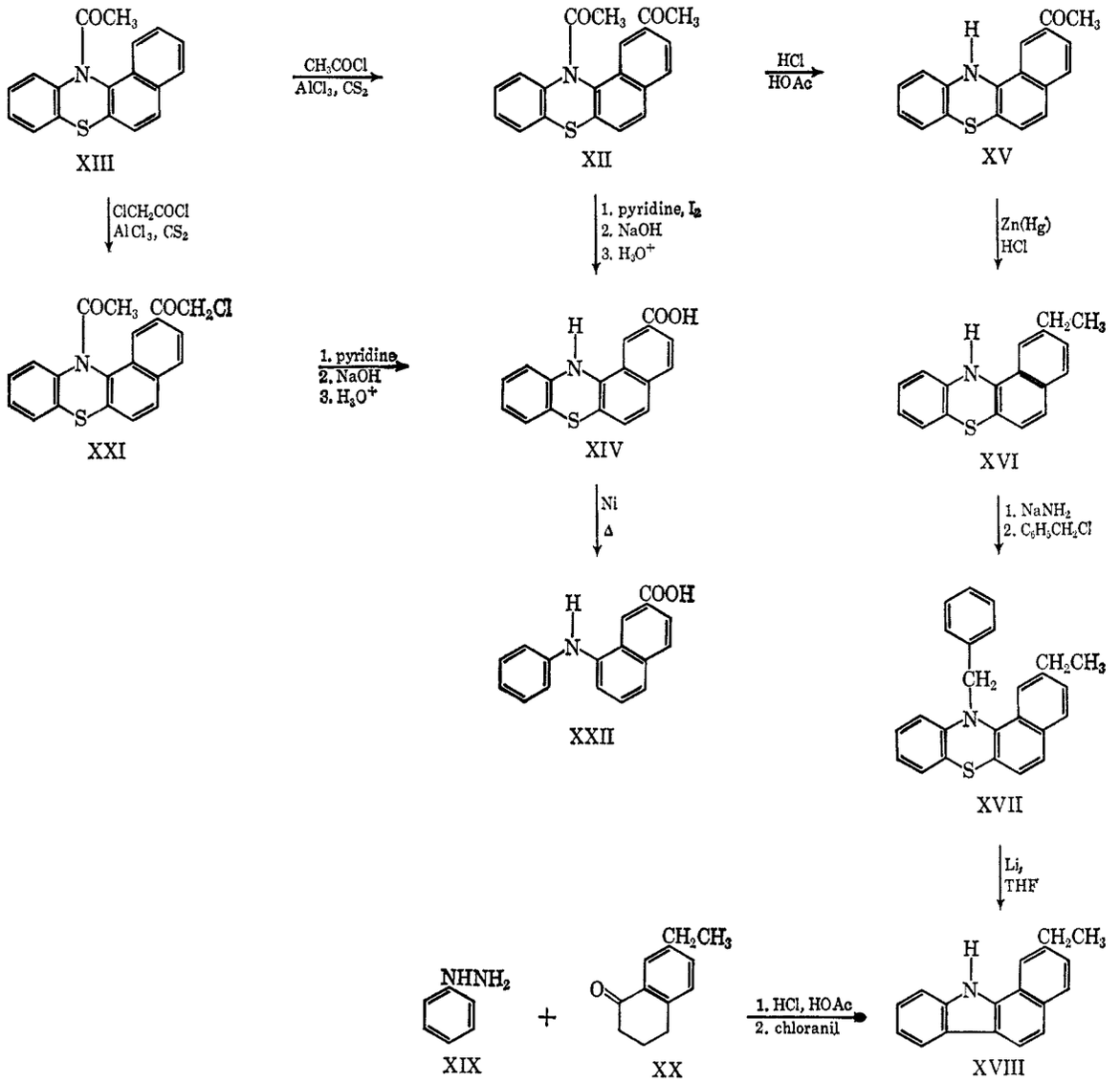


The same orientation was observed in the Friedel–Crafts chloroacetylation of VII as indicated by conversion of 10-chloroacetyl-12-acetylbenzo[*b*]phenothiazine (XII) into IX.

12H-Benzo[*a*]phenothiazine.—A diacetyl derivative (XII) was obtained in 52% yield when equimolar quantities of 12-acetylbenzo[*a*]phenothiazine (XIII)

(1) To whom inquiries concerning this paper should be sent.
(2) R. Scholl and C. Seer, *Ber.*, **44**, 1233 (1911).
(3) R. Baltzly, M. Harfenist, and F. J. Webb, *J. Am. Chem. Soc.*, **68**, 2673 (1946).
(4) A. Burger and J. B. Clements, *J. Org. Chem.*, **19**, 1113 (1954).

SCHEME III



and acetyl chloride were allowed to react with an excess of anhydrous aluminum chloride in carbon disulfide (Scheme III). The diacetyl derivative was degraded to a monocarboxylic acid (XIV). An infrared spectrum of XIV showed a strong carbonyl band at 5.90 μ. The methyl ester of XIV was obtained in 87% yield by the action of diazomethane. An infrared spectrum of the ester showed a strong carbonyl band at 5.87 μ.

The nmr spectra of 12H-benzo[*a*]phenothiazine and the methyl ester of XIV (Scheme III) were examined for possible clues on the position of substitution in the monoacylation product. While the aromatic proton region of these spectra was complex, an unsplit signal from a single proton appeared at relatively low field (δ = 8.43 ppm) in the methyl ester spectrum but not in the parent compound. This signal was considered likely to represent the 1 proton in the methyl ester with the low-field position owing both to adjacency to the carbonyl group and the α positioning on a naphthalene ring system. While the spectral data did not show conclusively the position of substitution, the above lead was the basis for subsequent synthetic work.

It has been established that the 2 position is indeed the position of acetylation by the series of reactions as described below and indicated in Scheme III. The N-acetyl group of XII was removed by hydrolysis with hydrochloric acid to yield 2-acetyl-12H-benzo[*a*]-phenothiazine (XV). Clemmensen reduction of XV gave 2-ethyl-12H-benzo[*a*]phenothiazine (XVI), which was treated with sodium amide followed by addition of benzyl chloride to yield 2-ethyl-12-benzylbenzo[*a*]-phenothiazine (XVII). Treatment of XVII with lithium metal in refluxing tetrahydrofuran yielded 2-ethylbenzo[*a*]carbazole (XVIII). The infrared spectrum and the melting point of XVIII were identical with those of an authentic sample of 2-ethylbenzo[*a*]carbazole prepared from phenylhydrazine (XIX) and 2-ethyl-3,4-dihydro-1-(2H)-naphthalenone (XX) according to the procedure of Buu-Hoi, Hoan, and Khoi.[5] A mixture melting point of the two products showed no depression.

Similar orientation was observed in the Friedel–Crafts chloroacetylation of XIII. The 2-chloroacetyl-12-acetylbenzo[*a*]phenothiazine (XXI) was converted to XIV. Raney nickel desulfurization of XIV yielded 8-(phenylamino)-2-naphthoic acid (XXII), a compound not previously reported.

(5) Ng. Ph. Buu-Hoi, Ng. Hoan, and Ng. H. Khoi, *J. Org. Chem.*, **15**, 957 (1950).

The acylation of these three ring systems occurred in a remarkably selective fashion. Even simple heterocyclic systems often tend to acylate *via* the Friedel–Crafts method at more than one position, and the benzophenothiazines contain ten nonequivalent ring positions potentially available for monosubstitution. In no case was a second monoacylation product isomer found and the chromatographic work-up of the reaction mixtures used in all cases would have probably revealed the presence of significant amounts of other isomers.

Some comments should be made on the dealkylation–desulfurization reaction carried out in the conversion of 2-ethyl-12-benzylbenzo[*a*]phenothiazine (XVII) to 2-ethylbenzo[*a*]carbazole (XVIII). The procedure followed the method of Gilman and Dietrich using lithium in tetrahydrofuran.[6] These workers converted N-ethylphenothiazine to N-ethylcarbazole (desulfurization) in 27% yield and N-benzylcarbazole to carbazole (dealkylation) in 28% yield. At the same time these workers[6] obtained no isolable product from an experiment with N-benzylphenothiazine. Prior to the experiment with 2-ethyl-12-benzylbenzo[*a*]phenothiazine, we carried out a pilot experiment with 12-methylbenzo[*a*]-phenothiazine and obtained benzo[*a*]carbazole in 24% yield. Apparently there has been no prior observation of a combination of dealkylation and desulfurization of N-alkylphenothiazines to carbazoles.

Experimental Section[7]

12-Acetylbenzo[*b*]phenothiazine (VII).—The reactants, 5.0 g (19 mmoles) of 12H-benzo[*b*]phenothiazine,[8] 2.7 g (39 mmoles) of sodium acetate, and 30 ml of acetic anhydride, were heated under reflux for 5 hr. The solution was poured over crushed ice. The solid product was collected and recrystallized from a mixture of ethanol and tetrahydrofuran. The yield of colorless needles, mp 222–223°, was 5.6 g (96%).

Anal. Calcd for $C_{18}H_{13}NOS$: C, 74.20; H, 4.47; N, 4.81. Found: C, 74.27, 74.43; H, 4.72, 4.67; N, 4.59, 4.74.

7-Chloroacetylbenzo[*c*]phenothiazine.—A solution of 3.7 g (32 mmoles) of chloroacetyl chloride and 5.0 g (20 mmoles) of 7H-benzo[*c*]phenothiazine[9] in 100 ml of benzene was heated under reflux for 2.5 hr. The benzene and excess chloroacetyl chloride were removed under reduced pressure and the residue was triturated with ligroin (bp 60–90°). The resulting solid was recrystallized from ethanol. There was obtained 5.4 g (83%) of colorless crystals, mp 121–122°.

Anal. Calcd for $C_{18}H_{12}ClNOS$: C, 66.35; H, 3.71; N, 4.30. Found: C, 66.12, 65.66; H, 3.92, 3.90; N, 4.05, 4.18.

2,12-Diacetylbenzo[*a*]phenothiazine (XII).—To a mechanically stirred mixture of 10.0 g (40 mmoles) of 12-acetylbenzo[*a*]-phenothiazine[10] and 3.9 g (50 mmoles) of acetyl chloride in 400 ml of dry carbon disulfide was added 14.5 g (0.11 mole) of anhydrous aluminum chloride in a period of 1 hr. The mixture was heated under reflux for 6 hr. The solvent was removed by decantation and crushed ice was added to the gummy residue. The resulting solid was dissolved in benzene and chromatographed over 60–100 mesh Florisil. Elution with a 3:2 mixture of benzene and chloroform gave 6.9 g (52%) of colorless crystals, mp 204–205°.

Anal. Calcd for $C_{20}H_{15}NO_2S$: C, 72.04; H, 4.53; N, 4.20. Found: C, 71.48, 71.45; H, 4.63, 4.67; N, 4.01, 4.12.

10,12-Diacetylbenzo[*b*]phenothiazine (VIII) was prepared from 12-acetylbenzo[*b*]phenothiazine as above. The solid was dissolved in benzene and the solution was placed on a 60–100 mesh Florisil chromatographic column. Elution with a 1:3 mixture of benzene and chloroform gave a colorless solid in the first fraction. The yield was 71%, mp 164–165°.

Anal. Calcd for $C_{20}H_{15}NO_2S$: C, 72.04; H, 4.53; N, 4.20. Found: C, 72.13, 72.11; H, 4.54, 4.53; N, 4.44, 4.38.

5,7-Diacetylbenzo[*c*]phenothiazine (II) was prepared in a similar fashion and 66% yield from 7-acetylbenzo[*c*]phenothiazine.[4] The product was recrystallized from ethanol. The melting point was 199–201°. The reported[4] value is 203–204°.

5-Chloroacetyl-7-acetylbenzo[*c*]phenothiazine (VI).—To a mechanically stirred mixture of 10.0 g (34 mmoles) of 7-acetylbenzo[*c*]phenothiazine and 13.3 g (0.10 mole) of anhydrous aluminum chloride in 200 ml of dry carbon disulfide was added 3.8 g (34 mmoles) of chloroacetyl chloride over a period of 1 hr. The mixture was kept at 25–30° for 1 hr and then heated under reflux for 4 hr. The solvent was removed by decantation and crushed ice was added to the gummy residue. The product was recrystallized from ethanol to yield 4.2 g (42%) of almost colorless crystals, mp 199–200°.

Anal. Calcd for $C_{20}H_{14}ClNO_2S$: C, 65.32; H, 3.81; N, 3.81. Found: C, 65.31, 65.48; H, 3.94 3.76; N, 3.72, 3.84.

10-Chloroacetyl-12-acetylbenzo[*b*]phenothiazine (XII) was prepared as above. The solid product was dissolved in benzene and the resulting solution was chromatographed over 60–100 mesh Florisil. A 1:3 mixture of benzene and chloroform eluted a colorless solid in 65% yield, mp 145–146°.

Anal. Calcd for $C_{20}H_{14}ClNO_2S$: C, 65.32; H, 3.81; N, 3.81. Found: C, 65.33, 65.28; H, 3.66, 3.74; N, 3.89, 3.72.

2-Chloroacetyl-12-acetylbenzo[*a*]phenothiazine (XXI), mp 200–201°, was prepared in similar fashion and 83% yield. The product was recrystallized from a 1:2 mixture of ethanol and tetrahydrofuran.

Anal. Calcd for $C_{20}H_{14}ClNO_2S$: C, 65.32; H, 3.81; N, 3.81. Found: C, 65.00, 65.20; H, 4.02, 3.93; N, 3.90, 3.76.

10-Chloroacetyl-12H-benzo[*b*]phenothiazine.—A mixture of 2.0 g (5 mmoles) of 10-chloroacetyl-12-acetylbenzo[*b*]phenothiazine, 15 ml of glacial acetic acid, and 10 ml of 50% aqueous hydrochloric acid was stirred at reflux temperature for 4 hr. The dark orange mixture was filtered while hot and the solid was washed several times with water. The solid was dissolved in benzene and chromatographed over a column of Woelm neutral alumina. Elution with benzene yielded 1.2 g (74%) of orange solid, mp 180–185° dec.

Anal. Calcd for $C_{18}H_{12}ClNOS$: C, 66.35; H, 3.71; N, 4.30. Found: C, 66.45, 66.27; H, 3.91, 3.85; N, 4.52.

5-Chloroacetyl-7H-benzo[*c*]phenothiazine was prepared as above. The product was recrystallized from ethanol to yield 63% of orange needles, mp 157–158° with some decomposition.

Anal. Calcd for $C_{18}H_{12}ClNOS$: C, 66.35; H, 3.71; N, 4.30. Found: C, 66.40, 66.17; H, 3.81, 3.69; N, 4.14. 4.08.

2-Acetyl-12H-benzo[*a*]phenothiazine (XV).—A mixture of 1.0 g (3 mmoles) of 2,12-diacetylbenzo[*a*]phenothiazine in 10 ml of concentrated hydrochloric acid and 5 ml of glacial acetic acid was heated under reflux for 1 hr. The mixture was allowed to cool to room temperature. The solid material was collected and dissolved in a 7:3 mixture of benzene and chloroform, and the solution was chromatographed over Woelm neutral alumina. Elution with the same solvent gave 0.71 g (82%) of yellow-orange solid, mp 203–204°.

Anal. Calcd for $C_{18}H_{13}NOS$: C, 74.20; H, 4.49; N, 4.82. Found: C, 73.70, 73.80; H, 4.45, 4.48; N, 4.80, 4.94.

5-Acetyl-7H-benzo[*c*]phenothiazine was prepared in similar fashion and 71% yield. The product was recrystallized from ethanol to yield orange platelets, mp 193–194°. The reported value[4] is 195–196°.

2-Ethyl-12H-benzo[*a*]phenothiazine (XVI).—A mixture of 4.0 g (12 mmoles) of 2-acetyl-12H-benzo[*a*]phenothiazine, 68.0 g of zinc amalgam, and 300 ml of 50% aqueous ethanol was placed in a 1-l. flask equipped with a mechanical stirrer and a dropping funnel. The mixture was vigorously stirred at room temperature and a 100-ml portion of concentrated hydrochloric acid was added in a period of 12 hr. A 34-g portion of zinc amalgam was added and 50 ml of hydrochloric acid was added in a period of 8 hr. The yellow-green solid was dissolved in benzene and chromatographed over a column of Woelm neutral alumina. Elution with benzene yielded 2.5 g (76%) of yellow solid, mp 147–149°. Thin layer chromatography on silica gel H, employing benzene as the developer, showed only one product (R_f 0.70) which was extremely sensitive to oxidation. Two subsequent

(6) H. Gilman and J. J. Dietrich, *J. Am. Chem. Soc.*, **80**, 380 (1958).

(7) Elementary microanalyses by Weiler and Strauss, Oxford, England. Melting points were determined on a Mel-Temp apparatus. Infrared spectra were determined on a Perkin-Elmer Infracord using the potassium bromide disk method. Nmr spectra were made on a Varian A-60 nmr spectrometer.

(8) J. A. Van Allan, G. A. Reynolds, and R. E. Adel, *J. Org. Chem.*, **27**, 1663 (1962).

(9) D. A. Shirley and W. E. Tatum, *J. Am. Chem. Soc.*, **81**, 496 (1959).

(10) P. B. Talukdar and D. A. Shirley, *ibid.*, **80**, 3462 (1958).

trials gave the same product in yields of 65 and 71%. A completely satisfactory elemental analysis of the product could not be obtained, but subsequent reactions indicated that it was essentially 2-ethyl-12H-benzo[*a*]phenothiazine.

5-Ethyl-7H-benzo[*c*]phenothiazine was prepared as above. The yield was 55%, mp 205–207°. A recorded[11] melting point is 208–209° dec.

10-Carboxy-12H-benzo[*b*]phenothiazine (IX). Method 1.—A solution of 7.0 g (19 mmoles) of 10-chloroacetyl-12-acetylbenzo[*b*]phenothiazine in 21 ml of pyridine was warmed at 90° for 1 hr and then allowed to stand at room temperature for 12 hr. The mixture was treated with 50 ml of dry ether and the 10-pyridiniumacetyl-12-acetylbenzo[*b*]phenothiazine chloride was collected and washed with dry ether. The compound was then hydrolyzed by heating at reflux temperature for 3 hr in 50 ml of 5% aqueous sodium hydroxide. The solution was filtered and the filtrate was neutralized with concentrated hydrochloric acid. The solid product was recrystallized from ethanol to yield 3.2 g (57%) of yellow crystals, mp 292–297° dec. Recrystallization from a mixture of benzene and tetrahydrofuran raised the melting point to 300–305° dec.

Anal. Calcd for $C_{17}H_{11}NO_2S$: C, 69.60; H, 3.78; N, 4.80. Found: C, 69.32, 69.40; H, 4.02, 3.91; N, 4.59, 4.78.

Method 2.—A solution of 1.0 g (3 mmoles) of 10,12-diacetylbenzo[*b*]phenothiazine and 0.2 g of iodine in 25 ml of dry pyridine was heated at 90–100° for 1 hr and allowed to stand at room temperature for 12 hr. The solution was concentrated to a small volume and 100 ml of absolute ethanol was added. The solid that separated was collected and washed with dry ether. The solid was hydrolyzed by heating at reflux temperature for 2 hr in 50 ml of 10% aqueous sodium hydroxide. The solution was filtered and the filtrate was neutralized with concentrated hydrochloric acid. The yellow solid was recrystallized from a mixture of benzene and tetrahydrofuran. The yield of yellow crystals, mp 297–302° dec, was 0.20 g (23%). The infrared spectrum was identical with that of the acid obtained by method 1. A mixture melting point of the products from methods 1 and 2 showed no depression.

10-Carbomethoxy-12H-benzo[*b*]phenothiazine.—An ethereal solution containing an excess of diazomethane was added to a suspension of 0.10 g (0.30 mmole) of 10-carboxy-12H-benzo[*b*]-phenothiazine in 25 ml of ether. The mixture was allowed to stand overnight in a hood. Yellow-orange crystals were obtained and these were recrystallized from ligroin (bp 60–90°) to yield 0.09 g (87%) of yellow-orange needles, mp 174–175°.

Anal. Calcd for $C_{18}H_{13}NO_2S$: C, 70.33; H, 4.26; N, 4.56. Found: C, 70.37, 70.14; H, 4.34, 4.36; N, 4.37, 4.27.

Desulfurization of 10-Carboxy-12H-benzo[*b*]phenothiazine with Raney Nickel.—About 50 g of Raney nickel catalyst was added to a suspension of 3.0 g (10 mmoles) of 10-carboxy-12H-benzo-[*b*]phenothiazine in 400 ml of absolute ethanol. The deep orange mixture was stirred under reflux for 6 hr. The catalyst was removed by filtration and the filtrate was concentrated to a small volume and allowed to cool. The crude yellow solid was recrystallized from ethanol, using Norit A, to yield 1.5 g (57%) of yellow crystals, mp 163–164°.

Anal. Calcd for $C_{17}H_{13}NO_2$: C, 77.5; H, 4.94; N, 5.32. Found: C, 77.05, 77.25; H, 5.10, 4.90; N, 5.60, 5.68.

7-(Phenylamino)-1-naphthoic Acid (X).—A mixture of 14.0 g (75 mmoles) of 7-amino-1-naphthoic acid,[12] 7.4 g (80 mmoles) of aniline, and 1.25 g of iodine was refluxed and stirred for 8 hr. The liberation of ammonia could be detected during the course of the reaction. After cooling, the solid mass was treated with 10% aqueous sodium carbonate solution and filtered. The filtrate was neutralized with concentrated hydrochloric acid to yield 0.90 g (5%) of yellow solid, mp 160–164°. The solid was recrystallized from ethanol to yield 0.70 g of yellow solid, mp 162–163°.

5-Carboxy-7H-benzo[*c*]phenothiazine (III).—This compound was prepared from 5,7-diacetylbenzo[*c*]phenothiazine in 12% yield and from 5-chloroacetyl-7-acetylbenzo[*c*]phenothiazine in 54% yield. The procedures described for the preparation of 10-carboxy-12H-benzo[*b*]phenothiazine were employed. The product was recrystallized from ligroin (bp 60–90°). The product was a yellow solid, mp 272–273° dec.

Anal. Calcd for $C_{17}H_{11}NO_2S$: C, 69.60; H, 3.75; N, 4.78. Found: C, 69.33, 69.43; H, 3.81, 3.65; N, 4.53, 4.58.

5-Carbomethoxy-7H-benzo[*c*]phenothiazine.—The procedure described for the preparation of 10-carbomethoxy-12H-benzo-[*b*]phenothiazine was employed. The product was recrystallized from ligroin (bp 60–90°) to yield 87% of orange crystals, mp 126–128°.

Anal. Calcd for $C_{18}H_{13}NO_2S$: C, 70.33; H, 4.26; N, 4.56. Found: C, 70.37, 70.46; H, 4.39, 4.42; N, 4.24, 4.77.

Desulfurization of 5-Carboxy-7H-benzo[*c*]phenothiazine with Raney Nickel.—The desulfurization was accomplished by the procedure described for the desulfurization of 10-carboxy-12H-benzo[*b*]phenothiazine. The product was precipitated from a sodium carbonate solution with concentrated hydrochloric acid. The yield of yellow needles, mp 183–184.5°, was 31%.

The melting point and infrared spectrum of this product were identical with those of an authentic sample of 3-(phenylamino)-1-naphthoic acid.

3-(Phenylamino)-1-naphthoic Acid (IV).—A mixture of 5.0 g (11 mmoles) of 3-amino-1-naphthoic acid sulfate,[13] 3.7 g of aniline, and 0.2 g of iodine was stirred under reflux for 8 hr. While the reaction mixture was still hot, it was poured over 250 ml of 10% aqueous hydrochloric acid to remove any unreacted aniline. The residue was dissolved in ethanol, treated with Norit A, and filtered. The filtrate was concentrated to a small volume and allowed to cool. The tarry precipitate was treated with 10% aqueous sodium hydroxide solution and filtered. The clear filtrate was neutralized with hydrochloric acid to yield a yellow solid. The solid was recrystallized from a 3:1 mixture of benzene and ligroin (bp 60–90°) to yield 0.60 g (23%) of yellow crystals, mp 183–184°.

Anal. Calcd for $C_{17}H_{13}NO_2$: C, 77.56; H, 4.94; N, 5.32. Found: C, 77.29; H, 5.12; N, 5.38.

2-Ethyl-12-benzylbenzo[*a*]phenothiazine (XVII).—A solution of 4.0 g (14 mmoles) of 2-ethyl-12H-benzo[*a*]phenothiazine in 50 ml of dry ether was slowly added to a suspension of approximately 28 mmoles of sodium amide in 25 ml of dry ether. The solution was heated under reflux for 30 min. A solution of 3.8 g (30 mmoles) of benzyl chloride in 5 ml of dry ether was added and refluxing was continued for 4 hr. The ether was removed by evaporation and the residue was dissolved in benzene. The benzene solution was chromatographed over Woelm neutral alumina. Elution with benzene yielded 3.8 g (75%) of yellow oil. Thin layer chromatography on silica gel H, using benzene as the developer, indicated one product (R_f 0.65).

Anal.[14] Calcd for $C_{25}H_{21}NS$: C, 81.70; H, 5.76; N, 3.81. Found: C, 81.54; H, 5.90; N, 3.69.

2-Ethylbenzo[*a*]carbazole (XVIII).—Lithium ribbon (approximately 1 mm thick) was washed thoroughly in benzene and then placed in ether. The lithium was scraped, while submerged in ether, until the surface was shiny. The cleaned lithium ribbon was then cut into squares approximately 2 mm in size.

A mixture of 3.0 g (8.2 mmoles) of 2-ethyl-12-benzylbenzo[*a*]-phenothiazine, 0.28 g (0.40 g-atom) of the lithium metal, and 100 ml of tetrahydrofuran (freshly distilled from lithium aluminum hydride) was stirred under reflux for 14 hr. The solvent was removed by evaporation and 50 ml of water was added to the residue. An excess of solid carbon dioxide was added to the suspension. The aqueous suspension was extracted with chloroform and the extract was dried over magnesium sulfate. The chloroform was removed by evaporation and the residual oil was dissolved in benzene. Chromatographic separation over Florisil, using benzene as the eluent, yielded 0.40 g of brown solid, mp 124–136°. The product was recrystallized from ethanol to yield 0.36 g (19%) of colorless crystals, mp 156–158°.

The melting point and infrared spectrum of this product were identical with those of an authentic sample of 2-ethylbenzo[*a*]-carbazole prepared by the procedure of Buu-Hoi, *et al.*[5]

Anal. Calcd for $C_{18}H_{15}N$: C, 87.72; H, 6.16; N, 5.70. Found: C, 87.99; H, 6.30; N, 5.65.

12-Methylbenzo[*a*]phenothiazine.—A suspension of 5.0 g (20 mmoles) of 12H-benzo[*a*]phenothiazine in 20 ml of dry ether was added to a suspension of approximately 40 mmoles of sodium amide in 20 ml of dry ether. The solution was heated under reflux for 5 hr. A solution of 7.1 g (50 mmoles) of methyl iodide in 50 ml of dry ether was added, and refluxing was continued for 4 hr. The ether was removed by evaporation and 100 ml of water was added to the residue. The resulting solid was dis-

(11) K. Gopalreddy, unpublished studies, University of Tennessee, 1960.
(12) N. J. Leonard and A. M. Hyson, *J. Org. Chem.*, **13**, 164 (1948).
(13) W. A. Jacobs and R. G. Gould, *Science*, **85**, 248 (1937).
(14) Galbraith Laboratories, Knoxville, Tenn.

solved in benzene and chromatographed over Florisil. Elution with benzene yielded 4.0 g (75%) of yellow solid, mp 115–116°.

Anal. Calcd for $C_{17}H_{13}NS$: C, 77.5; H, 4.95; N, 5.33. Found: C, 77.8; H, 5.12; N, 5.42.

11H-Benzo[*a*]carbazole.—Treatment of 12-methylbenzo[*a*]-phenothiazine with lithium in tetrahydrofuran was in similar fashion to the reaction described above. The product was eluted from a Florisil chromatographic column with a 1:1 mixture of ligroin (bp 60–80°) and benzene. The yield was 0.41 g (24%) of light tan solid, mp 222–223°, identical (melting point and infrared spectrum) with an authentic sample[15] of 11H-benzo[*a*]-carbazole.

2-Ethyl-12-methylbenzo[*a*]phenothiazine.—A solution of 4.0 g (14 mmoles) of 2-ethyl-12H-benzo[*a*]phenothiazine in 20 ml of dry ether was added to a suspension of approximately 30 mmoles of sodium amide in 20 ml of dry ether. An excess of methyl iodide was added and the resulting solution was stirred at room temperature for 6 hr. The ether was removed by evaporation and 100 ml of water was added to the residue. The mixture was warmed on a steam bath for 30 min. The aqueous suspension was extracted with benzene and the extract was dried over magnesium sulfate. Chromatographic separation of the benzene solution over Woelm neutral alumina, using benzene as the eluent, yielded 1.8 g (44%) of viscous oil.

Anal.[14] Calcd for $C_{19}H_{17}NS$: C, 78.36; H, 5.84; N, 4.81. Found: C, 78.16; H, 5.74; N, 4.75.

Desulfurization of 2-Carboxy-12H-benzo[*a*]phenothiazine (XIV) with Raney Nickel.—The desulfurization of 2-carboxy-12H-benzo[*a*]phenothiazine was accomplished in 42% yield by the procedure described for the desulfurization of 10-carboxy-12H-benzo[*b*]phenothiazine. The product was recrystallized from ethanol to yield yellow crystals, mp 220–222°.

Anal. Calcd for $C_{17}H_{13}NO_2$: C, 77.5; H, 4.94; N, 5.32. Found: C, 77.69, 77.75; H, 5.08, 5.05; N, 5.08, 5.28.

(15) Prepared by C. J. Campbell following procedures of Ng. Ph. Buu-Hoi, Ng. Hoan, and Ng. Khoi, *Rec. Trav. Chim.*, **69**, 1053 (1949); Ng. Ph. Buu-Hoi, Ng. Hoan, and Ng. Khoi, *J. Org. Chem.*, **14**, 492 (1949).

Registry No.—VII, 7775-60-2; 7-chloroacetylbenzo-[*c*]phenothiazine, 3640-00-4; XIV, 7731-92-2; VIII, 7731-93-3; II, 7731-94-4; VI, 7731-95-5; XII, 7731-96-6; XXI, 7731-97-7; 10-chloroacetyl-12H-benzo[*b*]phenothiazine, 7731-98-8; 5-chloroacetyl-7H-benzo[*c*]phenothiazine, 7731-79-5; XV, 7771-19-9; 5-acetyl-7H-benzo-[*c*]phenothiazine, 7775-58-8; XVI, 7775-59-9; IX, 7731-80-8; 10-carbomethoxy-12H-benzo[*b*]phenothiazine, 7731-81-9; X, 7731-82-0; III, 7731-83-1; 5-carbomethoxy-7H-benzo[*c*]phenothiazine, 7731-84-2; IV, 7731-85-3; XVII, 7731-86-4; XVIII, 7731-87-5; 12-methylbenzo[*a*]phenothiazine, 6937-18-4; 2-ethyl-12-methylbenzo[*a*]phenothiazine, 7731-89-7; XXII, 7731-90-0.

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Free-Radical Chlorination of Alkylsilanes. II.[1] The Controlling Factors in the Sulfuryl Chloride Chlorination of Alkylchlorosilanes

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The relative reactivities of various carbon–hydrogen bonds of seven different alkylchlorosilanes toward the sulfuryl chloride chlorination have been determined in carbon tetrachloride solvent in the presence of toluene as standard. The reactivity data indicate that the trichlorosilyl group exhibits a negative ($-I$) inductive effect, whereas the dimethylchlorosilyl group displays a positive ($+I$) inductive effect. It is also concluded that the polar effect of the methyldichlorosilyl group is very small in magnitude. The decrease in reactivity of carbon–hydrogen bonds adjacent to a silicon atom is observed and ascribed to the reduced possibilities of the incipient radicals for hyperconjugation.

The free-radical chlorination of alkylchlorosilanes, R_nSiCl_{4-n}, has received extensive attention in the field of synthetic organosilicon chemistry,[2] but studies of the directing effects of the changes in the silane structure on chlorination have been rather semiquantitative. Thus, Sommer and co-workers studied the sulfuryl chloride chlorination of ethyltrichloro-,[3] diethyldichloro-,[4] triethylchloro-,[5] tetraethyl-,[6] and *n*-propyltrichlorosilane,[7] and determined isomer distributions based upon the amounts of the isolated products. Their results show a progressive change in the directive effects of silicon, with $SiCl_3$ directing strongly to the β carbon and $SiEt_3$ being strongly α directing. They also noticed deactivation of the α positions in ethyltrichlorosilane[3] and *n*-propyltrichlorosilane[7] by proximity of the $SiCl_3$ group. More recently, Steward and Pierce[8] chlorinated 3,3,3-trifluoropropyltrichlorosilane using chlorine gas and ultraviolet light to determine the effect of the trifluoromethyl and trichlorosilyl groups on the product distribution. In this instance the carbon–hydrogen bonds in the α position to silicon were found to be about 6.2 times more susceptible to attack by a chlorine radical than the carbon–hydrogen bonds in the β position.

Unfortunately, however, the detailed analysis of much of earlier data concerning the chlorination of alkylchlorosilanes[3–13] was hampered by the lack of the

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