olefins employed were a mixture of internal olefins and possessed the following composition: C_9, 10.2; C_{10}, 50.6; C_{11}, 38.1; C_{12}, 1.0; average mol wt, 142.4. The autoclave was charged with 160 g (8 mol) of HF and 10 g (0.55 mol) of H_2O and pressured to 2500 psig with CO. The temperature was 45–50° and 45 min were required to pump in 70 g of olefins used. Distillation of 140 g of HF left a light-colored residue which was poured on ice and made basic with NaOH.

Extraction with hexane gave 3.7 g of neutrals. Acidification of the aqueous solution after hexane extraction gave 69.3 g of crude acids. Distillation of 66.8 g gave essentially one cut weighing 59.1 g (63% yield) of colorless acids, bp 100–104° (0.15 mm), $n^{20}D$ 1.4380, with 2.2 g of heavy residue remaining.

Anal. Found: C, 71.44; H, 12.18; mol wt, 185; neut equiv, 5.18 mequiv/g.

Carboxylation of 1,5-Cyclooctadiene with CO–HF–H_2O.—The 1-l. Monel autoclave was charged with 215 g (10.8 mol) of HF and 25 g (1.4 mol) of H_2O and pressured to 1300 psig with CO. 1,5-Cyclooctadiene (108 g, 1 mol) was added over a period of 2 hr to the mixture heated at 45–50°. After stirring for an additional 1 hr, the CO was vented and the reactor was cooled. HF (176 g) was removed by distillation and the residue was poured on ice and made basic with NaOH followed by extraction with $CHCl_3$. The bottom $CHCl_3$ layer was filtered and dried over $MgSO_4$. An intermediate red-brown layer was very viscous and seemed insoluble in both $CHCl_3$ and H_2O. The top aqueous layer was reextracted with $CHCl_3$ and then acidified with H_2SO_4. Removal of the $CHCl_3$ from the basic extract left 37.7 g of a viscous liquid which was probably the same as the intermediate layer. The acidified layer was extracted with *n*-hexane to give 42.6 g of acids after drying over $MgSO_4$. Distillation of 37.4 g through a 6-in. Vigreux column provided 22.7 g of a heart cut. Redistillation gave the pure acid, bp 91–93° (0.2 mm), $n^{20}D$ 1.4867 [lit.[9] bp 132° (25 mm)]. The nmr spectrum supported the assigned structure, **7**, a singlet at τ −2.7 (RCO_2H) and a multiplet at τ 7–9 in a ratio of 13:1 with no evidence for olefinic protons.

Anal. Calcd for $C_9H_{14}O_2$: C, 70.14; H, 9.15; mol wt, 154. Found: C, 70.00; H, 9.08; mol wt, 152; neut equiv, 6.57 mequiv/g.

Carboxylation of Cyclododecene with CO–HF.—The autoclave was charged with water (10 g) and HF (160 g) and pressured to 2300 psig CO at 45–50°. Cyclododecene (50.4 g, 0.30 mol) dissolved in 100 ml of cyclohexane was added over a period of 40 min. After a reaction time of 3 hr, the reactor was cooled, the CO was vented, and 350 ml of H_2O followed by 150 ml of hexane was added to the autoclave. The contents were drained into a plastic separatory funnel. The upper organic layer was shaken with 10% NaOH to form carboxylic acid salts. Evaporation of the remaining organic layer provided 15.5 g of neutrals. Acidification of the aqueous layer with H_2SO_4 and chloroform extraction gave 42 g of nearly colorless acids. Distillation provided 24.8 g of a heart cut, bp 137–149° (0.3–0.5 mm), of acids which solidified on cooling. Recrystallization (hexane) gave cyclododecanecarboxylic acid, mp 97–98° (lit.[10] mp 97.5°).

Registry No.—**6**, 34402-87-4; **7**, 7403-22-7; HF, 7664-39-3; CO, 630-08-0; 1-pentene, 109-67-1; cyclohexene, 110-83-8; methyl cyclohexanoate, 4630-82-4; 7-tetradecene, 10374-74-0; 1,5-cyclooctadiene, 111-78-4; cyclododecene, 1501-82-2.

Acknowledgment.—The assistance of Mr. Bill Loffer in performing many of the experiments is gratefully recognized.

(9) G. Pregaglia and G. Gregorio, *Chim. Ind. (Milan)*, **45**, 1065 (1963).

(10) G. Bo, P. Perras, and Y. Colleuille (to Rhone-Poulenc), French Patent 1,286,803 (Mar 9, 1962); *Chem. Abstr.*, **57**, 14967 (1962).

The Tiffeneau–Demjanov Reaction on Phenyl-Fused Cyclopentyl Systems

WILLIAM E. PARHAM* AND CHRISTOPHER S. ROOSEVELT

Department of Chemistry, University of Minnesota, Minneapolis, Minnesota 55455

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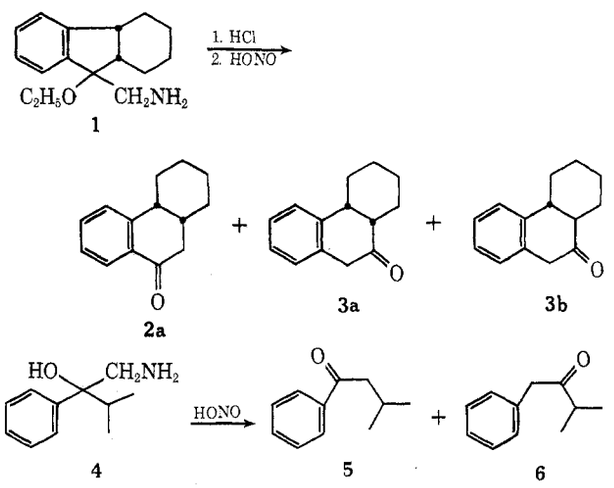
The diastereomeric amine hydrochlorides **10a** and **10b** were prepared and their reactions with nitrous acid were studied. Change of stereochemistry at C-9 in **10** is not a significant factor affecting aryl to alkyl migration in this system; however, it is noted that the ketone product ratios changed markedly changing the ethoxy group at C-9 (in **1**) to hydroxy (**10a** or **10b**).

The Tiffeneau–Demjanov reaction (the action of nitrous acid on β-amino alcohols) of phenyl-fused cyclopentyl systems, in which the migration may be by either the phenyl group or alkyl group, has not heretofore been investigated. A modified Tiffeneau–Demjanov reaction on one diastereomer of the β-amino ether **1** (Scheme I) gave an unusually large ratio of alkyl migration product **2a** to aryl migration product **3**[1] (ratio **2a**/**3** = 1/0.2–0.9) as compared to the analogous monocyclic system **4** (ratio **5**/**6** = 1/31). The observed preferential alkyl migration was attributed to the geometric requirement for phenyl migration. In **1** the phenyl nucleus cannot rotate to the position assumed to be most favorable for migration because of the constraint inherent in the fused system.[1] An alternate explanation, based on dependence of stereochemistry at C-9, was not eliminated, however, since attempts to prepare the other diastereomer of **1** and the two diastereomers **10a** and **10b** were unsuccessful.[1]

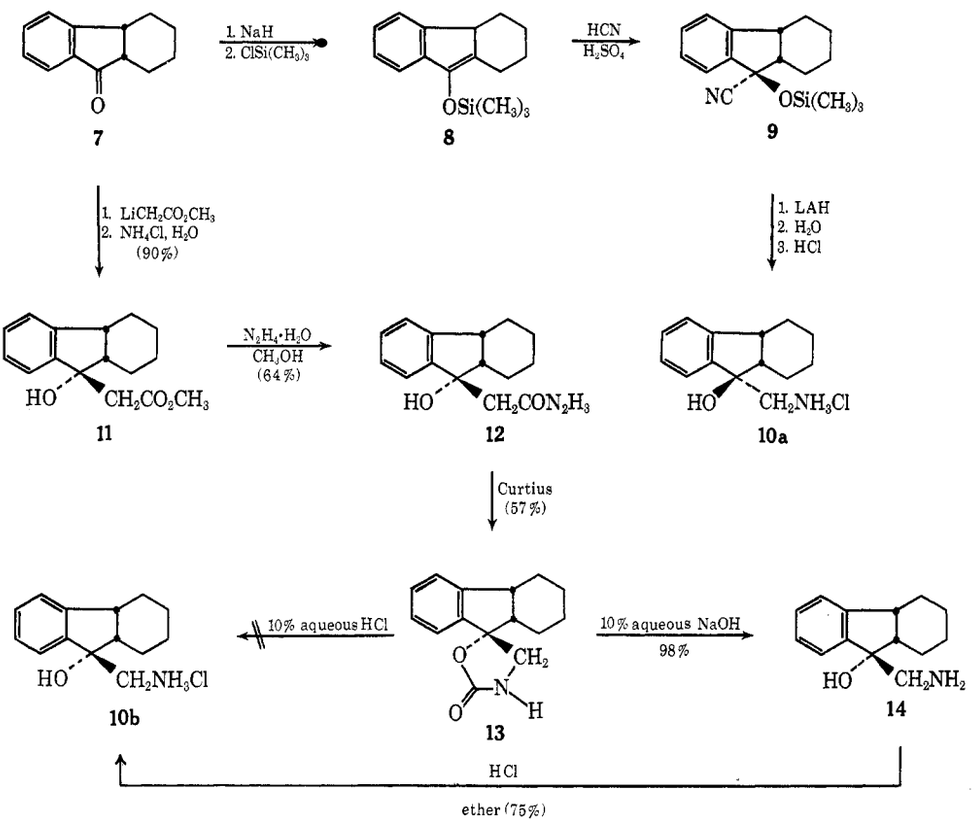
This report describes preparation of the diastereomeric amine hydrochlorides **10a** and **10b**, and considers in greater detail factors which affect product ratios in the Tiffeneau–Demjanov reaction in these fused systems.

SCHEME I



(1) W. E. Parham and L. J. Czuba, *J. Amer. Chem. Soc.*, **90**, 4030 (1968).

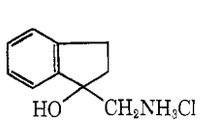
SCHEME II



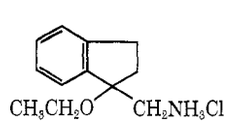
Results

The two diastereomeric β-amino alcohol hydrochlorides **10a** and **10b** were prepared as shown in Scheme II. The determination and/or assignment of stereochemistry is presented in the Discussion. The amine hydrochloride **10a** was prepared as previously described;[2] **11** was prepared from **7** and lithiomethyl acetate by a modification of the general procedure described by Rathke.[3] Use of methyl acetate rather than ethyl acetate was found to be markedly superior in this system, since the methyl ester **11** gave a higher yield of acid hydrazide **12**; hydrolysis of the intermediate oxazolidone was effected by alkali since use of aqueous hydrochloric acid led to extensive dehydration of **10b**.

The indan derivatives **15** and **16**, analogous to **10** and **1**, were of interest and their preparation is described in the Experimental Section.



15



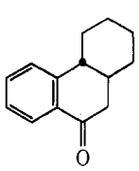
16

The amine hydrochlorides **10a** and **10b** were treated with aqueous sodium nitrite and a catalytic amount of hydrochloric acid. Product identification was effected by ir, gc, and nmr comparisons with authentic samples. Yields were determined by combined gc and nmr analyses and are shown in Table I. The hexahydrophenanthrone **2b** was shown not to be present in the product by comparison of data obtained from the product with those of an authentic sample of **2b**.[4]

TABLE I

YIELDS OF KETONES FROM AMINES

Amine	Yield, % 2a	3a	3b
10a	25.6	55	0.7
10b	32.6	50.3	2.8



2b

The amino alcohol hydrochloride **15** and the amino ether hydrochloride **16** were treated with sodium nitrite under identical conditions used for **10a** and **10b**; however, no definitive results were obtained. A brown-black solid was obtained in both cases and neither α- nor β-tetralone could be detected. It was subsequently shown that β-tetralone, but not α-tetralone, is unstable to the conditions of reaction; however, owing to the uncertainty of what processes may have occurred it would not seem justifiable to conclude that only β-tetralone was formed in these reactions.

Discussion

Stereochemistry.—The two diastereomeric racemates **10a** and **10b** were prepared from **7** as shown in

(2) W. E. Parham and C. S. Roosevelt, *Tetrahedron Lett.*, 923 (1971).
(3) M. W. Rathke, *J. Amer. Chem. Soc.*, **92**, 3222 (1970).
(4) An authentic sample of **2b** was generously supplied by Professor Wendel E. Nelson, University of Washington.

Scheme II. The stereochemistry of the cyclohexyl–cyclopentyl ring fusion (C-4a and C-9a) was determined by examination of the products from the Tiffeneau–Demjanov reaction on both diastereomers. The Tiffeneau–Demjanov reaction is known[5,6] to proceed with retention of configuration about the migrating carbon atom. The products resulting from migration of the 9a carbon of **10** would then be either ketone **2a** or **2b** depending upon the stereochemistry of the starting material. The ketone resulting from C-9a migration prepared from both diastereomers prepared as shown in Scheme II was found to be the cis ketone **2a**. The two diastereomers of **10** then differed only at the C-9 position, and both have a cis ring fusion.

The stereochemistry of **10a** and **10b** at C-9 was not confirmed, but assignment can be made with reasonable confidence. In the synthesis of **10b** from **7**, the stereochemistry at C-9 was determined by the addition of lithiomethyl acetate to the ketone **7**. By analogy with Cram's rule[7] the lithiomethyl acetate should add across the carbonyl group on the least hindered side. Models clearly show that the least hindered side of **7** contains the 4a-H and 9a-H, *not* the cyclohexyl ring. The addition product should therefore be **11**, and, since none of the subsequent steps would affect the stereochemistry at C-4a, C-9a, and C-9, the amino alcohol hydrochloride can be assigned structure **10b**.

The isomer of **10** prepared by the silyl enol ether route was assigned structure **10a** since other possible structures were excluded by the above arguments. This assignment is also reasonable since the final steric configuration was defined by the addition of hydrogen cyanide to the silyl enol ether **8**. Since the stereochemistry of the product at C-4a and C-9a is known, the proton must first add to **8** to give a cis ring fusion. The nitrile should then add to the less hindered side of the planar carbonium ion. Models show that the trimethylsilyl group is oriented to the side containing the 4a-H and 9a-H, and that the product should be **9**, which would lead to **10a**.

Tiffeneau–Demjanov Reaction.—The ratios of products obtained by aryl to alkyl migration in the Tiffeneau–Demjanov reaction of **10a** and **10b** were 2.17/1 and 1.63/1, respectively. The aryl migration products **3** formed in preference to alkyl migration product **2a** for both diastereomers. By comparison, the open-chain analog **4** gave aryl to alkyl migration in the ratio of 31/1, while the modified Tiffeneau–Demjanov reaction[1] on **1** gave 0.2 to 0.9/1 aryl to alkyl migration.

The large decrease in the aryl to alkyl migration ratio in going from the acyclic compound **4** to the cyclic compound **10** is attributed at least in part to the steric control exerted by the rigid fused system. This same effect has been noted[1] in the modified Tiffeneau–Demjanov reaction involving **1**. In fused systems, such as **10**, rotation of the phenyl group is restricted and the phenyl π orbitals cannot effectively overlap with the empty p orbitals of the developing carbonium ion.[1] The amount of phenyl migration is consequently reduced and the amount of alkyl migration is increased in comparison to nonrestricted acyclic analogs.

The change of stereochemistry at C-9 in **10** is not a significant factor affecting aryl to alkyl migration in this system. Two types of steric control have now been noted that can affect migratory aptitudes of groups in the Tiffeneau–Demjanov reaction. In addition to that discussed above,[1] the second relates to the conformation of the cyclohexyl ring in the transition state[8,9] (*i.e.*, leading to the more stable chair conformation). Failure to observe a significant dependence of stereochemistry at C-9 in **10a** and **10b** on migratory ratios does not assist in assessment of importance of this second steric effect, since, in **10**, the central five-membered ring is relatively flat, which should lead to a six-membered ring transition state that is intermediate between a chair and a boat for either direction of migration.

It is of interest to note that the ketone product ratios were changed markedly by changing the hydroxy group to ethoxy (compare **10** to **1**) with no change in stereochemistry at C-9. Since both intermediates are readily available, this observation is important in synthesis. The only factor that could have caused the difference was the relative effects of ethyl relative to hydrogen. Whether this effect is steric or electronic in nature, or a combination, will be the subject of further study.

Experimental Section

Gas chromatographic analyses were performed on a Varian Aerograph 90-P with thermal conductivity detector; gas flow was 60 cc/min unless otherwise noted. Neither melting points nor boiling points were corrected.

Methyl 9-*trans*-Hydroxy-1,2,3,4,4a-*cis*,9a-*cis*-hexahydrofluoren-9-*cis*-ylacetate (11).—Methyl acetate (7.74 g, 0.104 mol) was added dropwise over a period of 6 min under dry nitrogen to a stirred solution of hexamethyldisilazyllithium[3,10] (0.090 mol) in dry tetrahydrofuran (90 ml) at −78°. Additional tetrahydrofuran (15 ml) was added to the cooled solution, followed by dropwise addition during 30 min of a solution containing 1,2,3,4,4a-*cis*,9a-*cis*-hexahydrofluoren-9-one (**7**)[1,11] (13.45 g, 0.0725 mol) in tetrahydrofuran (15 ml). The yellow solution was aged for 45 min at −78°. A solution of ammonium chloride 6.55 g, 0.122 mol) in water (55 ml) was added, and the mixture was warmed to room temperature. The tetrahydrofuran layer was separated and combined with two 50-ml ether extractions of the aqueous layer. The yellow solution was dried over magnesium sulfate and concentrated,[12] leaving a yellow oil (21.36 g). A small amount of the oil (2.17 g) was purified by chromatography on a neutral alumina (activity I) column developed with 10% ether and 90% benzene. A white solid was recovered from the column and was used as a seed crystal to crystallize the remaining crude product, which was recovered as a white solid (16.96 g, 90% yield, mp 48–58°). The crude hydroxy ester **11** was purified by recrystallization from petroleum ether (bp 30–60°) to yield the analytically pure sample as a white solid: mp 59–60°; ir (CCl_4) ν 3485 (s, OH), 1724 cm^{-1} (s, C=O); nmr (CCl_4) τ 2.60–3.05 (m, 4 H, C_6H_4), 6.05 (broad s, 1 H, OH), 6.35 (s, 3 H, CH_3), 6.80 (broad s, 1 H, benzo H), 7.40 (s, 2 H, CH_2CO_2), 7.45–9.35 (m, 9 H, alkyl H); uv (95% ethanol) λ_{max} 260 mμ (ϵ 2175), 265 (2550), 271 (2650).

Anal. Calcd for $C_{16}H_{20}O_3$: C, 73.82; H, 7.74. Found: C, 74.05; H, 7.93.

9-*trans*-Hydroxy-1,2,3,4,4a-*cis*,9a-*cis*-hexahydrofluoren-9-*cis*-ylacetic Acid Hydrazide (12).—Methyl hydroxy ester 11 (5.45 g, 0.0210 mol), methanol (5 ml), and hydrazine hydrate (9 ml)

(5) H. Heussner, P. T. Herzig, A. Furstand, and P. A. Plattner, *Helv. Chim. Acta*, **33**, 1093 (1950).
(6) F. Ramirez and S. Stafiej, *J. Amer. Chem. Soc.*, **77**, 134 (1955).
(7) E. L. Eliel, "Stereochemistry of Carbon Compounds," McGraw-Hill, New York, N. Y., 1962, p 69.
(8) G. DiMaio, *Tetrahedron*, 2291 (1967).
(9) G. DiMaio and P. A. Tardella, *ibid.*, 2069 (1966).
(10) E. H. Amonoo-Neizer, R. A. Shaw, D. O. Slovkin, and B. C. Smith, *J. Chem. Soc.*, 2997 (1965).
(11) S. Dev, *J. Indian Chem. Soc.*, **34**, 169 (1957).
(12) Rotary evaporator under aspirator pressure.

were combined and heated at the reflux temperature for 2 hr. The methanol was removed by distillation and the remaining solution was allowed to cool to room temperature. One volume of water was added and a white, opaque mixture resulted. The crude product was recovered by filtration as a yellow gum, which was crystallized from ether to give the acid hydrazide **12** as a white solid (3.50 g, 64% yield, mp 117–120°). The hydrazide was recrystallized to constant melting point from ether to give the analytically pure sample as a white solid: mp 127.5–128.5°; ir (Nujol) ν 3335 (s), 3240 (s), 1648 cm^{-1} (s); nmr ($CDCl_3$) τ 1.91 (broad s, 1 H, OH), 2.50–3.10 (m, 4 H, C_6H_4), 4.90–6.70 (m, 3 H, NH and NH_2), 6.92 (broad s, 1 H, 4a-CH), 7.25–9.65 (m, 11 H, CH_2 and 9a-CH, acetate CH_2 singlet at τ 7.60).

Anal. Calcd for $C_{15}H_{20}N_2O_2$: C, 69.20; H, 7.74; N, 10.56. Found: C, 69.06; H, 7.99; N, 10.50.

A repeat of the experiment afforded a 77% yield of crude hydrazide (mp 118–122°) by allowing the opaque, white mixture, formed by addition of one volume of water to the hydrazine hydrate solution, to stand for 24 hr.

Spiro[1′,2′,3′,4′,4a′-*cis*,9a′-*cis*-hexahydrofluorene-9′-*cis*,5-oxazolidin]-2-one (13).—A solution of sodium nitrite (1.07 g, 15.5 mmol) in water (10 ml) was added dropwise over 7 min to a stirred suspension of the hydrazide **12** (2.80 g, 10.8 mmol) in a solution of acetic acid (1.07 g, 17.8 mmol) in water (100 ml) at 0°. After 50 min benzene was added and stirring was continued for an additional 25 min. The mixture was warmed to room temperature and the benzene layer was separated and combined with two 50-ml benzene washings of the aqueous layer. The benzene solution was dried over magnesium sulfite, then heated at the reflux temperature for 30 min. The benzene solution was concentrated[12] to give a yellow oil, which solidified upon standing to give the oxazolidone **13** as yellow crystals (2.40 g, 91% crude yield, mp 135–144°), ir (Nujol) ν 3275 (s), 1755 (s), 1735 cm^{-1} (s). The crude product was recrystallized from ether to give a tan solid: 1.50 g (57% yield); mp 157–157.5°; ir (Nujol) ν 3290 (m), 1753 (s), 1729 cm^{-1} (s); ir ($CHCl_3$) ν 3290 (m), 1730 cm^{-1} (s, broad); nmr ($CDCl_3$) τ 2.40–3.05 (m, 4 H, C_6H_4), 3.05–3.50 (m, 0.5 H, NH), 6.30 (s, 2 H, CH_2N), 6.45–7.20 (m, 1 H, 4a-CH), 7.20–8.90 (m, 9 H, 9a-CH and CH_2); uv (95% ethanol) λ_{max} 258 mμ (ϵ 350), 264 (500), 270 (580).

Anal. Calcd for $C_{15}H_{17}NO_2$: C, 74.05; H, 7.04; N, 5.76. Found: C, 73.83; H, 6.85; N, 5.54.

9-*cis*-Methylamino-1,2,3,4,4a-*cis*,9a-*cis*-hexahydrofluoren-9-*trans*-ol (14).—The oxazolidone **13** (5.65 g, 0.0232 mol) was suspended by stirring in a 10% aqueous sodium hydroxide solution (150 ml) for 16 hr at 110°. The cooled solution was treated with three 100-ml portions of ether. The combined ether portions were dried over magnesium sulfate and concentrated[12] to give a light brown oil (5.31 g). Addition of a small amount of ether caused the oils to crystallize. Removal[12] of the ether left the amino alcohol **14** as a tan solid (5.31 g, 106% crude yield, mp 111–112°), ir (Nujol) ν 3345 (m), 3120 cm^{-1} (broad). Recrystallization of the solid from ether–petroleum ether (bp 60–70°), afforded pure **14** as a white solid: 4.89 g (98% yield); mp 111.5–112.5°; nmr ($CDCl_3$) τ 2.50–3.05 (m, 4 H, C_6H_4), 6.60–7.00 (m, 1 H, 4a-CH), 7.00–7.40 (broad s, 2 H, NH_2), 7.40–9.35 (m, 12 H, OH, CH_2 and 9a-CH).

Anal. Calcd for $C_{14}H_{19}NO$: C, 77.38; H, 8.81; N, 6.45. Found: C, 77.16; H, 8.58; N, 6.22.

A portion of the pure amino alcohol (2.54 g, 0.0117 mol) was dissolved in ether (100 ml) and anhydrous hydrogen chloride was bubbled through the solution. Filtration of the mixture gave impure amine hydrochloride **10b**, which was recovered as a white solid (2.24 g, 75% crude yield, mp 209–215°). Recrystallization of this product from ethanol–ether afforded the analytically pure sample as a white powder (mp 229–230° with noticeable decomposition above 183°), ir (Nujol) ν 3340 (m), 3218 (s), 3190 (s), 3100 cm^{-1} (s) (not identical with ir of **10a**, mp 198.5–199.5°[2]).

Anal. Calcd for $C_{14}H_{20}ClNO$: C, 66.26; H, 7.95; N, 5.52; Cl, 13.97. Found: C, 66.39; H, 8.09; N, 5.49; Cl, 13.79.

3-Ethoxyindene.—A mixture of 1-indanone (29.73 g, 0.225 mol), ethanol (100 ml), triethyl orthoformate (40.73 g, 0.275 mol), and hydrochloric acid (two drops) was stirred for 17 hr at room temperature. The resulting red solution was concentrated by distillation at atmospheric pressure until the ethanol and excess triethyl orthoformate were removed. The remaining undistilled red oil was then distilled under vacuum on a spiral wire column (18 × 0.8 cm) to yield the crude product as a clear, colorless oil [18.88 g, 52% crude yield, bp 72–75° (0.15 mm)]. Purification of the crude ether was achieved by chromatography on an alumina (activity III) column, developed with petroleum ether. The pure product was isolated as a cloudy, colorless oil: 16.11 g (45% yield); $n^{28}D$ 1.5448; ir (neat) ν 1615 cm^{-1} (m, C=C); nmr (CCl_4) τ 2.45–3.07 (m, 4 H, C_6H_4), 4.91 (t, J = 2.25 Hz, 1 H, CH), 6.02 (q, J = 6 Hz, 2 H, CH_2CH_3), 6.90 (d, J = 2.25 Hz, 2 H, benzylic CH_2), 8.61 (t, J = 6 Hz, 3 H, CH_3); uv (95% ethanol) λ_{max} 256 mμ (ϵ 8560). The essentially pure sample was distilled again through the spiral wire column to give a clear, colorless oil, bp 63–64° (0.35 mm). An analytical sample was prepared by preparative gas chromatography (3% SE-30 on Chromosorb W, 80–100 mesh, 5 ft × 1/4 in., 140°).

Anal. Calcd for $C_{11}H_{12}O$: C, 82.47; H, 7.55. Found: C, 82.60; H, 7.67.

1-Ethoxyindan-1-ylmethylamine Hydrochloride (16).—3-Ethoxyindene (6.12 g, 0.0387 mol) was added in one lot to hydrogen cyanide[13] (15 ml) containing sulfuric acid (two drops) at ice-bath temperature. The resulting solution was stirred for 3 hr at ice-bath temperature, and then for 12 hr at room temperature. Excess hydrogen cyanide was removed by passing a stream of dry nitrogen gas above the solution. The crude cyano ether was recovered as a dark red oil. The oil was dissolved in ether (25 ml) and the ether solution was added dropwise during 15 min to a stirred suspension of lithium aluminum hydride (1.42 g, 0.0374 mol) in ether (50 ml) heated at the reflux temperature under a dry nitrogen atmosphere. The mixture was stirred for 30 min at room temperature, then 9% aqueous sodium hydroxide (20 ml) was added. The crude product was extracted from the aqueous mixture with three 25-ml portions of ether. The ether solution was dried over magnesium sulfate and concentrated[12] to give a dark green oil (4.87 g). The dark green oil contained unreduced nitrile [ir (neat) ν 2208 cm^{-1} (w, CN)] and was again treated with lithium aluminum hydride (0.61 g, 0.0016 mol) as described above to give a green oil (4.08 g), nmr (CCl_4) two triplets at τ 8.90 and 8.95 in the approximate ratio 3:2. Ether saturated with hydrogen chloride gas was added dropwise at ice-bath temperature to an ether (20 ml) solution of the green oil (1.01 g) until no more solid formed. The amine hydrochloride was obtained as a white solid (0.61 g, 29% yield based on 3-ethoxyindene) which recrystallized twice from ethanol–ether to afford analytically pure **16** as a white powder, mp 145–230° dec.

Anal. Calcd for $C_{12}H_{18}ClNO$: C, 63.29; H, 7.97; N, 6.15. Found: C, 63.35; H, 8.02; N, 6.11.

Attempted preparation of **16** by reaction of the amino alcohol with concentrated hydrochloric acid in ethanol led to the isolation of an off-white, platelike solid (41% yield based on **19**, mp 246–247°), which was assumed to be the unsaturated amine hydrochloride.

Anal. Calcd for $C_{10}H_{12}ClN$: C, 66.12; H, 6.66; N, 7.71; Cl, 19.52. Found: C, 66.35; H, 6.63; N, 7.37; Cl, 19.52.

Reaction of Amine Hydrochlorides with Nitrous Acid. A. 10a.—A sample of amine hydrochloride **10a** (0.3317 g, 1.315 mmol) was dissolved in water (8 ml) and cooled to ice-bath temperature. A solution of sodium nitrite (0.2743 g, 3.965 mmol) in water (3 ml) was added with stirring. A catalytic amount of hydrochloric acid (1 drop) was added and the aqueous solution was stirred for 2 hr at ice-bath temperature, and then for 15 hr at room temperature. The product was extracted with three 10-ml portions of ether and the ether solution was dried ($MgSO_4$) and concentrated[12] to yield an orange oil (0.2290 g).

Authentic samples[1] of **2a**, **2b**,[4] **3a**, and **3b** were available. Product identification and analyses were made by gc and nmr analysis similar to the procedure described in detail[1] for mixtures of the same ketones derived from **1**. The yields of products follow: **3a**, 55%; **3b**, 0.7%; **2a**, 25.6%. The reaction was repeated four times; the yields of total ketonic products varied somewhat but the ratio of **3a**, **3b**, and **2a** was essentially the same.

When catalytic amounts of hydrochloric acid were not employed in the diazotization step the total yield of ketonic products was reduced; however, there was essentially no change in ratios of **3a**, **3b**, and **2a**. The aqueous layer obtained from the diazotization contained, in all cases studied, unchanged amine hydrochloride. The only by-product noted was a small amount of ketonic material (ν 1710 cm^{-1}) to 6.3% yield. No **2b** (aromatic protons ortho to carbonyl, τ 1.75–2.10) was present in any products.

(13) K. Ziegler, "Organic Syntheses," Collect. Vol. I, Wiley, New York, N. Y., 1932, p 314.

B. 10b.—The reaction was conducted as above and gave **2a** (32.6% yield), **3a** (50.3% yield), and **3b** (2.8% yield).

C. 15 and 16.—The reactions of **15**[2] and **16** were carried out essentially as described above. The product was a brown-black solid; no α- or β-tetralone was detected by gc analysis (comparison with authentic samples, 5% DC-710 on Chromosorb W, 80–100 mesh, 5 ft × 1/4 in., 150°). It was subsequently shown that β-tetralone, but not α-tetralone, reacts readily (to give a black gum) when stirred at 0° with a mixture of 9% aqueous hydrochloric acid to which sodium nitrite is added.

Registry No.—**10b**, 34402-93-2; **11**, 34410-05-4; **12**, 34402-94-3; **13**, 34402-95-4; **14**, 34402-96-5; **16**, 34402-97-6; **19**, 34402-98-7; 3-ethoxyindene, 34402-99-8.

Benzocyclobutene and 2-Phenylethyl Chloride as Alkylating Agents in the Friedel–Crafts Reaction[1]

LEONARD H. SCHWARTZ,* JACK LANDIS, SHEILA B. LAZARUS,[2a] AND STEPHEN H. STOLDT[2b]

Department of Chemistry, The City College of The City University of New York, New York, New York 10031

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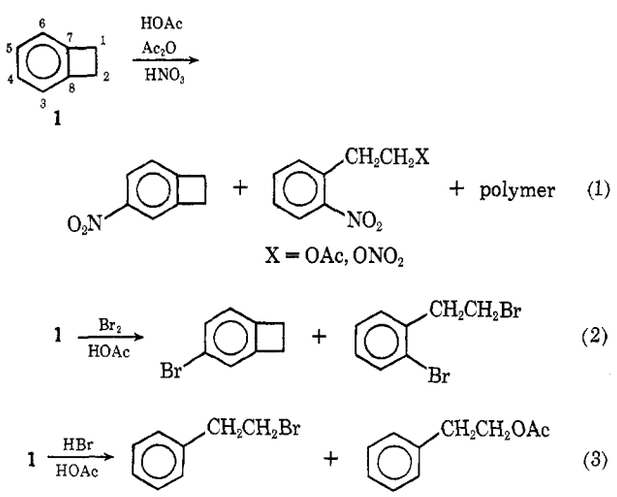
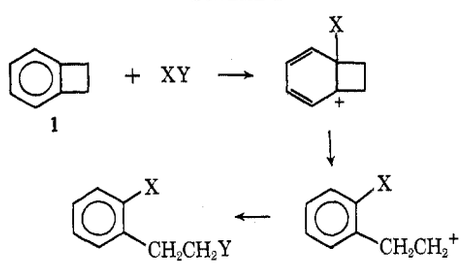
Friedel–Crafts reactions of benzocyclobutene and 2-phenylethyl chloride with benzene and toluene are studied at various temperatures. On the basis of identical product ratios with toluene, lack of positional rearrangement at the aryl rings of 1-chloro-2-*p*-tolylethane and 1-chloro-2-*m*-tolylethane on reaction with benzene, and various stereochemical arguments, it is concluded that in the presence of $AlCl_3$, benzocyclobutene is directly converted to 2-phenylethyl chloride before reaction with the aromatic hydrocarbon. Incomplete reaction of 1,1-dideuterio-2-*p*-tolylethyl chloride with benzene at 40° in the presence of $AlCl_3$ reveals that the starting material undergoes partial isomerization of the CH_2 and CD_2 groups. This differs with previous results with 2-phenylethyl-*1*-^{14}C chloride at −5° and suggests that in our case the intermediate phenonium ion, or its equivalent, reverts in part to starting material.

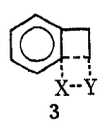
This paper reports the results of a study of benzocyclobutene (**1**) and 2-phenylethyl chloride (**2**) as alkylating agents under Friedel–Crafts conditions. The reactions of benzocyclobutene (**1**) and its derivatives with electrophilic reagents generally follow two competing pathways.[3] Aromatic substitution may occur, mainly at the 4 position with possibly minor amounts of substitution at the 3 position, or electrophilic attack may occur at a bridgehead carbon to open the four-membered ring and give ortho-substituted 2-phenylethyl derivatives. Some examples are nitration (eq 1),[3a,d] bromination (eq 2),[3f] and reaction with HBr in acetic acid (eq 3).[3d] Lloyd and Ongley have presented



SCHEME I



arguments concerning the mechanism of the ring-opening reaction.[3f] They have argued that the pathway involving a benzenonium ion (Scheme I) is not involved, since the formation of the benzenonium ion would be precluded by strain effects. It was further argued that this pathway requires generation of an ortho-substituted 2-phenylethyl cation, which is energetically improbable. It was concluded that the mechanism for ring opening involves a multicentered transition state (**3**).



3

The Friedel–Crafts reaction of 2-phenylethyl chloride (**2**) with aromatic hydrocarbons has been studied by isotopic labeling. Lee, Forman, and Rosanthal have found that 2-phenylethyl-*1*-^{14}C chloride with excess $AlCl_3$ in the presence of anisole yields *p*-methoxybibenzyl with the ^{14}C equally distributed between the methylene groups.[4] Two general mechanisms were discussed which could not be distinguished: (1) the same intermediate is involved in rearrangement and alkylation; (2) rearrangement and alkylation occur by separate processes. McMahon and Bunce studied the

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(2) (a) National Science Foundation Undergraduate Research Participant, 1966–1969; (b) City University of New York Research Assistant, 1964–1966; National Aeronautics and Space Administration Trainee, 1966–1967.

(3) (a) L. Horner, H.-G. Schmelzer, and B. Thompson, *Chem. Ber.*, **93**, 1774 (1960); (b) L. Horner, P. V. Subramaniam, and E. Eiben, *Tetrahedron Lett.*, 247 (1965); (c) *Justus Liebigs Ann. Chem.*, **714**, 91 (1968); (d) J. B. F. Lloyd and P. A. Ongley, *Tetrahedron*, **20**, 2185 (1964); (e) *ibid.*, **21**, 2281 (1965); (f) *ibid.*, **21**, 245 (1965).

(4) C. C. Lee, A. G. Forman, and A. Rosenthal, *Can. J. Chem.*, **35**, 220 (1957).