Structure of 2-Methyl-p-dioxene (XIV).—A pentane solution of bromine was added to 0.29 g. of XIV dissolved in 10 ml. of pentane until the color of bromine barely faded. The pentane was expelled by nitrogen at room temperature, the resulting oil dissolved in dilute hydrochloric acid, and the mixture warmed on the steam bath for 0.5 hr. To half of this solution was added 1 ml. of phenylhydrazine and enough acetic acid to give a clear solution. A flocculent yellow precipitate of osazone formed immediately, m.p. 144.5–146°; lit. 145°, yield 69%.[33] The dibenzoate of ethylene glycol was isolated from the other half of the hydrolysate by procedures described above; yield, 18%.

Treatment of XIII and XIV with Mercuric Acetate.—A sample of XIV (0.0023 mole) was treated in water solution with mercuric acetate (0.0023 mole) at room temperature. There was an immediate grayish precipitate which soon turned black. A sample of XIII under similar treatment gave only traces of very light gray precipitate. In another experiment, XIII was tested with methanolic suspension of mercuric acetate. There was no immediate reduction to mercury. After standing 24 hr., a trace of black mercury developed. Under similar conditions, XIV gave an immediate black precipitate of mercury.

N.m.r. Spectra of XIII and XIV (by Dr. A. Louis Allred).—The n.m.r. spectrum of XIV consisted of three peaks with the areas in the ratio 1:4:3. The most intense peak is in the methylene absorption region and is relatively broad. The peak of intensity 1 in the olefin absorption region and the peak of intensity 3 in the methyl absorption region are split slightly, because of weak spin–spin coupling. The n.m.r. spectrum of XIII consisted of three peaks, with partially resolved fine structure, in the absorption region of methylene groups and terminal olefins. Two small peaks with appropriate intensities, chemical shifts, and fine structure indicated that about 5% of the sample consisted of compound XIV. The n.m.r. spectra were obtained with a Varian Associates high-resolution spectrometer at 40 Mc. and room temperature.

Acknowledgment.—We wish to thank the National Science Foundation for a summer faculty research fellowship held by Professor Eric S. Graham during 1957. We also wish to thank Dr. James G. Traynham of Louisiana State University for helpful discussions and the loan of facilities during the preparation of this manuscript.

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[33] H. V. Pechmann, *Ber.*, **20**, 2543 (1887).

A Product of the Chemical Reduction of *o*-Benzenediacetonitrile

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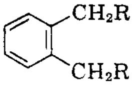
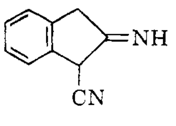
The sodium reduction product of *o*-benzenediacetonitrile (Ia) which was assigned the structure 2-methyl-2-indanamine (IIIa) by von Braun is shown to be 2-indanamine (IIIc). An authentic synthesis of the former substance is described. Some indanylhydrazines and related substances with monoamine oxidase activity were prepared. The acid-catalyzed degradation of benzyl-type hydrazines to the amine and olefin is reported, in some cases (X), the reaction being surprisingly facile. Mechanisms for the unusual loss of a carbon atom during the reduction of Ia and for the new elimination reaction of benzylhydrazines are suggested.

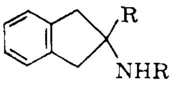
In 1892 Zanetti[4] discovered that the reduction of *o*-benzenediacetonitrile (Ia) with sodium and alcohol yielded two products, one a diamine to which he assigned structure Ib and the second a monoamine of $C_{10}H_{13}N$ composition. A reinvestigation of this reaction by von Braun twenty-four years later[5] led to the same results. While accepting the Zanetti structure Ib for the diamine, von Braun devoted his attention to the monoamine. Its oxidation to phthalic acid, its inertness to catalytic or chemical reduction and its formation also from the sodium–alcohol reduction of 1-cyano-2-iminoindane (II), a compound readily obtained by a sodium ethoxide-induced cyclization of *o*-benzenediacetonitrile (Ia),[6] convinced him that he was dealing with an indanamine. He further observed that exhaustive methylation of the amine, Hofmann elimination of the quaternary ammonium salt and formation of an anisal derivative of the resulting indene afforded a crystalline product which proved to be different from the anisylidene derivative of the then known 1-methylindene. Hence von Braun considered it to be the derivative of 2-methylindene and was led to conclude that the monoamine is 2-methyl-2-indanamine (IIIa).



Ia. R = CN
b. R = CH_2NH_2
c. R = CH_2CONH_2



II



IIIa. R = CH_3, R′ = H
b. R = H, R′ = COC_6H_5
c. R = R′ = H
d. R = H, R′ = NH_2

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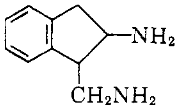
[3] Department of Chemistry, Iowa State University. Present address: Department of Chemistry, Indiana University, Bloomington, Ind.

[4] C. V. Zanetti, *Gazz. Chim. It.*, **22** (II), 510 (1892).

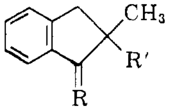
[5] J. von Braun, O. Kruber, and E. Danziger, *Ber.*, **49**, 2645 (1916).

[6] C. W. Moore and J. F. Thorpe, *J. Chem. Soc.*, **93**, 165 (1908).

By the middle 1930's the Zanetti diamine structure Ib was under attack. Its physical properties[4,5] were different from those found for the diamine obtained by the Hofmann degradation of the diamide Ic[7] and by the Raney nickel-catalyzed hydrogenation of Ia.[8] When finally it was shown that *both* Zanetti amines were also products of the sodium–alcohol reduction of II, the structure of the diamine could be revised to IV.[9] While no further work has been reported on the structure of the monoamine, it has been suggested that the latter is formed by reductive deamination of IV to a cyclopropyl amine and a further reduction to the methylcarbinylamine IIIa.[9]



IV

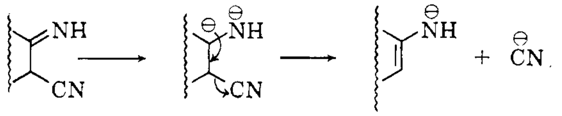


Va. $R = O, R' = CO_2C_2H_5$
b. $R = H_2, R' = CO_2C_2H_5$
c. $R = H_2, R' = CO_2H$

Our interest in the chemical and pharmacological properties of indanamines and our consequent attraction to the Zanetti–von Braun monoamine as well as the complete non-acceptability of its structure (IIIa)[5] or of the suggested mode of its formation[9] on the basis of present-day views of organic chemistry led to our redetermination of its structure. While several analyses of the amine fitted the previously suggested $C_{10}H_{13}N$ formula, elemental analyses of its salts were more compatible with a $C_9H_{11}N$ formulation. However, a proton magnetic resonance spectrum of a deuterochloroform solution of the N-benzoyl derivative of the amine resolved the problem. The spectrum supported only structure IIIb for the benzamide: an aromatic nine-proton multiplet at δ = 7.0–7.8 p.p.m., a broad NH signal at 6.4–6.8 p.p.m., a one-proton quartet centered at 4.85 p.p.m. (J = 4.7 and 7.6 c.p.s.) characteristic of the methine next to the amido group, a four-proton octet at 3.11 p.p.m. (J = 4.7, 7.6, and 15.3 c.p.s.) corresponding to the benzyl hydrogen atoms and *no* C-methyl signal. Hence the Zanetti–von Braun monoamine must be 2-indanamine (IIIc). This was confirmed by its identity and that of its derivatives with authentic IIIc, produced by the α-nitrosation of 1-indanone and hydrogenation–hydrogenolysis of the resulting oximinoketone, and its derivatives, respectively. Furthermore, the amine proved to be different from authentic 2-methyl-2-indanamine (IIIa) prepared in the following manner: *o*-Carboxycinnamic acid was converted to ethyl 1-oxo-2-methyl-2-indanecarboxylate (Va) by several modifications of a procedure by Titley,[10] the most significant being the use of sodium hydride in the Dieckmann ring closure of ethyl *o*-carbethoxydihydrocinnamate and direct C-methylation of the sodio derivative without isolation of the intermediate. Sodium borohydride reduction of Va followed by palladium-catalyzed hydrogenation yielded the ester Vb whose acid hydrolysis led to its acid Vc. Curtius degradations of the latter by the method of Beard and Burger[11] gave 2-methyl-2-indanamine (IIIa).

A reinterpretation of von Braun's Hofmann elimination results[5] forces one to conclude that he had in hand indene rather than 2-methylindene. Indeed the melting point of the anisal derivative of his hydrocarbon is the same as that reported for 1-*p*-anisylideneindene.

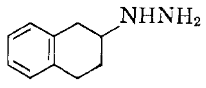
While the diamine IV is a normal product of the reduction of both imino and nitrile groups in II, the amine IIIc represents the product of an unusual fragmentation and reduction of II. The interesting formation of 2-indanamine (IIIc) can best be rationalized by assuming that reduction at the site of the imino group occurs first and that the intermediate one-electron or two-electron addition product (VI) undergoes cyanide elimination. Protonation of the product (VII) and further reduction of the resulting ketimine leads to the amine IIIc.



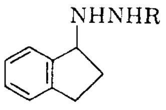
II VI VII

The analgesic activity of 2-indanamine has already been reported to be about that of morphine in mice.[12]

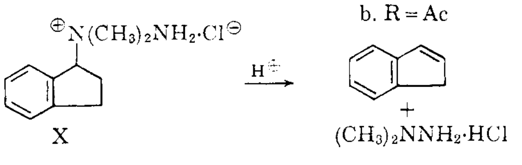
Because of the interesting pharmacological activity of IIIc, the hydrazines VIII and IIId were prepared (by displacement of the proper tosylates by hydrazine). These are closely related to the β-phenethylhydrazine monoamine oxidase inhibitors first reported by Biel and co-workers[13] and proved to be as active.



VIII



IXa. R = Ac
b. R = Ac



X

During an investigation of methods of preparation of indanyl hydrazines, it was discovered that the hydrazine IXa as well as its acetyl derivative

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(7) K. Fries and H. Bestian, *Ber.*, **69**, 715 (1936).

(8) P. Ruggli and A. Staub, *Helv. Chim. Acta*, **20**, 925 (1937).

(9) E. Eidebenz, *Ber.*, **74**, 1798 (1942).

(10) A. Titley, *J. Chem. Soc.*, 2571 (1928).

(11) C. Beard and A. Burger, *J. Org. Chem.*, **26**, 2335 (1961).

(12) L. Witkin, C. F. Huebner, F. Galdi, E. O'Keefe, P. Spitalleta, and A. Plummer, *J. Pharm. Exp. Therap.*, **133**, 400 (1961).

(13) J. H. Biel, A. E. Drucker, F. Mitchell, E. P. Sprengeler, P. A. Nuhfer, A. C. Conway, and A. Horita, *J. Am. Chem. Soc.*, **81**, 2805 (1959).

IXb is degraded to indene and the hydrazine moiety on treatment with hydrochloric acid. This observation to our knowledge represents the first instance of a facile acid-catalyzed elimination of hydrazine from a benzyl-type hydrazine.

A limited survey was made to delineate the scope of the reaction. The reactivity of other related compounds in acid was examined. The reaction in 6 *N* hydrochloric acid at 20° goes to completion yielding the olefin from IXa and 1,2,3,4-tetrahydro-1-naphthylhydrazine in ten minutes and from 1,1-dimethyl-1-(1-phenylethyl)hydrazonium bromide in twenty minutes. The compound to be degraded the most readily is X. Although an aqueous solution of the hydrazonium chloride is stable indefinitely, addition of acid at room temperature to make the concentration 6 *N* results in an almost immediate separation of indene. As would be expected, 1-indanamine and IIId are stable to acid. As a first approximation, the following mechanism is suggested for this facile elimination of hydrazine from benzylhydrazines. Strong acid diprotonates the hydrazine which then, to relieve the instability caused by the proximity of the two positive charges, fragments to the relatively stabilized benzyl carbonium ion and the hydrazonium ion. The faster reaction of X over that of IXa is evidence for this.

Experimental

2-Indanamine (IIIc) from *o*-Benzenediacetonitrile.—In essence, the procedure of von Braun[5] was followed. A solution of 20 g. of *o*-benzenediacetonitrile in 800 ml. of ethanol was heated to reflux on the steam bath. The heat was removed and 60 g. of sodium added through a wide bore condenser as rapidly as possible without allowing the alcohol or amine to boil out of the condenser. (The rate of reaction may be increased by the use of a magnetic stirrer during addition.) The reaction mixture was cooled to room temperature, diluted with ethanol, acidified with 15% aqueous hydrochloric acid, and the ethanol evaporated *in vacuo* after filtering off the sodium chloride. The residue was cooled, made basic with ammonium hydroxide, and the organic material extracted into ether. The ether solution was washed with water, dried over sodium sulfate, and evaporated. Distillation of the residue yielded 5.5 g. of material; b.p. 103–105°/12 mm., reported b.p. 118–119°/18 mm.[5]

Anal. Calcd. for $C_{10}H_{13}N$: C, 81.58; H, 8.90; N, 9.52. Calcd. for $C_9H_{11}N$: C, 81.16; H, 8.33; N, 10.52. Found: C, 80.76; H, 8.72; N, 9.74.

The base was converted to the hydrochloride and after two recrystallizations from ethanol melted 234–239°, reported m.p. 241° by von Braun.[5]

Anal. Calcd. for $C_{10}H_{13}N \cdot HCl$: C, 65.39; H, 7.68; N, 7.63. Calcd. for $C_9H_{11}N \cdot HCl$: C, 63.71; H, 7.13; N, 8.26. Found: C, 63.74; H, 7.26; N, 8.26.

The melting point of a mixture with an authentic sample of 2-indanamine hydrochloride prepared as below was 242–245°. The N-acetyl derivative from the von Braun amine prepared as described as below melted at 125–126° and when mixed with an authentic sample of N-2-indanylacetamide showed no depression. The N-benzoyl derivative melted at 154–157° and showed no depression in melting point when mixed with an authentic sample of N-2-indanylbenzamide. The infrared spectra of these two derivatives are identical to those of the authentic specimens. Kenner and Mathews[14] report the N-acetyl and N-benzoyl derivatives of 2-indanamine to melt at 126–127° and at 155°, respectively.

2-Indanamine from 1-Indanone.—To an alcohol solution of 100 g. of 1-indanone (0.758 mole) was added 115 ml. (0.855 mole) of isoamyl nitrite at 15°. The mixture was then carefully treated with 20 ml. of concentrated hydrochloric acid. The temperature was not allowed to rise above 50°. After the addition was completed, the reaction mixture was stirred at 50° for 0.5 hr. The 2-nitroso-1-indanone which separated on cooling was collected, washed with ethanol to remove excess isoamyl nitrite, and air-dried; yield 58 g., m.p. 214–220°. Five grams of the nitroso ketone dissolved in 130 ml. of acetic acid containing 4 ml. of concentrated sulfuric acid was reduced catalytically with 1.6 g. of palladium black (100%) at 40 p.s.i. and 60°. The sulfuric acid was neutralized with 6 *N* sodium hydroxide and the sodium sulfate removed by filtration. The filtrate was evaporated to dryness, the residue taken up in a minimum amount of water and the aqueous solution made basic with 50% potassium hydroxide. It was extracted with ether, the ether washed with a small amount of water, and after drying over sodium sulfate, evaporated to dryness. The oily base was converted to the hydrochloride (2.6 g.) m.p. 246–249° dec. by treating with ethanolic hydrogen chloride.

Anal. Found: C, 63.39; H, 7.32; N, 8.01.

N-2-Indanylacetamide.—To a stirred mixture of 1 g. of 2-indanamine hydrochloride, 5 g. of ice, and 1.5 ml. of acetic anhydride was added dropwise a 40% sodium hydroxide solution. After the mixture was permanently basic, the acetamide was filtered and recrystallized from ethanol, m.p. 125–126°; yield 0.96 g.

Anal. Calcd. for $C_{11}H_{13}NO$: C, 75.40; H, 7.48; N, 7.99. Found: C, 75.50; H, 7.51; N, 8.09.

N-2-Indanylbenzamide (IIIb).—The benzamide prepared by the Schotten–Baumann technique melted at 155–158° after recrystallization from ethanol.

Anal. Calcd. for $C_{16}H_{15}NO$: C, 79.97; H, 6.71; N, 6.22. Found: C, 79.97; H, 6.42; N, 5.98.

Ethyl *o*-Carbethoxydyhydrocinnamate.—Twenty grams of *o*-carboxycinnamic acid[10] and 8 g. of sodium hydroxide were dissolved in 100 ml. of water and hydrogenated at 1500 p.s.i. and 85° over 5 g. of Raney nickel. Hydrogen uptake was complete in 30 min. The catalyst was filtered off and the solution acidified with hydrochloric acid. The crude acid, m.p. 158–160°, was dried and esterified as described by Titley.[10]

Ethyl 1-Oxo-2-methyl-2-indanecarboxylate (Va).—An efficiently stirred mixture of 31 g. of ethyl *o*-carbethoxydihydrocinnamate and 18 g. of a 50% sodium hydride in mineral oil dispersion in 200 ml. of toluene was gradually heated on a Glass-Col heater. When the inside temperature reached about 80° a vigorous exothermic reaction took place. External heating was removed and the reaction allowed to proceed under its own heat of reaction. After 30 min. the reaction was complete leaving a gelatinous, bulky precipitate of the sodium salt of the β-keto ester. A solution of 20 g. of methyl iodide in 75 ml. of anhydrous dimethylformamide was added and the mixture stirred at reflux for 4 hr. The reaction mixture was diluted with 500 ml. of water and the organic phase separated, dried, and the toluene removed by distillation *in vacuo* on the steam bath. The mineral oil layer separating was removed and the residue distilled at 0.3 mm. Twenty grams of ethyl-1-oxo-2-methyl-2-indanecarboxylate was collected at 118–119°.

Anal. Calcd. for $C_{13}H_{14}O_3$: C, 71.55; H, 6.43. Found: C, 71.54; H, 6.90.

2-Methyl-2-indanecarboxylic Acid (Vc).—To a solution of 10 g. of the above keto ester in 100 ml. of ethanol was added over a period of 30 min., 1 g. of sodium borohydride

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(14) J. Kenner and A. Mathews, *J. Chem. Soc.*, **105**, 747 (1914).

while keeping the reaction at room temperature by cooling. After standing an additional 30 min., the major part of the ethanol was distilled *in vacuo*, water added, and the hydroxy ester extracted with ether. After drying over sodium sulfate, the ether solution was filtered and evaporated to dryness. The crude ethyl 1-hydroxy-2-methylindanecarboxylate was hydrogenated over 1 g. of palladium black in 50 ml. of acetic acid containing 3 ml. of concentrated hydrochloric acid for 12 hr. after which time one molar equivalent had been absorbed. The catalyst was filtered off and most of the solvent distilled *in vacuo*. The residue was diluted with water and extracted with ether. Extraction of the ether with aqueous sodium hydroxide gave, on acidification, a small amount of the desired 2-methyl-2-indanecarboxylic acid. The neutral fraction contained in the ether was distilled at 83–85° and 0.2 mm. Seven grams of ethyl-2-methyl-2-indanecarboxylate (Vb) was collected.

Anal. Calcd. for $C_{13}H_{16}O_2$: C, 76.44; H, 7.90. Found: C, 76.03; H, 8.28.

The ester was refluxed with a mixture of 35 ml. of concentrated hydrochloric acid and 100 ml. of acetic acid for 2 days. The solvents were largely distilled *in vacuo*, the residue diluted with water and extracted with ether. Removal of the ether gave the crystalline Vc. The acid fractions were combined and recrystallized twice from methanol yielding 5 g. of 2-methyl-2-indanecarboxylic acid, m.p. 102–104°.

Anal. Calcd. for $C_{11}H_{12}O_2$: C, 74.97; H, 6.86. Found: C, 74.64; H, 6.88.

2-Methyl-2-indanamine (IIIa).—To a stirred solution of 3.1 g. of Vc in a mixture of 25 ml. of acetone, 5 ml. of water, and 2.8 ml. of triethylamine cooled to −5° was added a solution of 1.9 ml. of ethyl chloroformate in 5 ml. of acetone. After stirring at −5° for 30 min., a solution of 1.65 g. of sodium azide in 10 ml. of water was added with stirring and the mixture stirred for 1 hr. at 0°. This was poured into a mixture of 250 ml. of cold saturated sodium chloride solution and 100 g. of ice and extracted five times with 50 ml. of anhydrous ether. The combined ether extracts were dried over sodium sulfate, evaporated to dryness *in vacuo* at 30° and the residual oily azide dissolved in 25 ml. of toluene. This solution was gradually warmed on the steam bath to 100° until nitrogen evolution ceased (about 30 min.). The solvent was removed *in vacuo* and the oily isocyanate refluxed with 20 ml. of 6 N hydrochloric acid for 12 hr. The solution was evaporated to dryness *in vacuo* leaving the crystalline amine hydrochloride (IIIa) as a residue. A few milliliters of acetone were added and it was filtered and recrystallized from *n*-propyl alcohol–ether, m.p. 215–217°.

Anal. Calcd. for $C_{10}H_{13}N \cdot HCl$: C, 65.39; H, 7.63; N, 7.63. Found: C, 65.27; H, 7.78; N, 7.38.

2-Indanylhydrazine (IIId).—To a solution of 5 g. of 2-indanol in 25 ml. of pyridine was added 11 g. of *p*-toluenesulfonylchloride in portions with external cooling to keep the temperature at about 30°. After standing overnight, the mixture was poured into ice–water, and the sulfonate filtered. After recrystallization from acetone, it melted at 110–111°. This same compound has been reported recently by H. Bodot, *et al.*[15] (m.p. 109°).

Anal. Calcd. for $C_{16}H_{16}O_3S$: C, 66.66; H, 5.59. Found: C, 66.89; H, 5.70.

A mixture of 6.5 g. of the sulfonate and 4 ml. of anhydrous hydrazine in 25 ml. of ethanol was refluxed for 6 hr. The tosylate salt of IIId obtained by removal of the solvent *in vacuo* was recrystallized from ethanol, m.p. 163–164° dec.

Anal. Calcd. for $C_9H_{12}N_2 \cdot C_7H_8N_2O_3S$: C, 59.99; H, 6.29; N, 8.75. Found: C, 60.35; H, 6.38; N, 9.10.

1,2,3,4-Tetrahydro-2-naphthylhydrazine (VIII).—To a solution of 25 g. of 3,4-dihydro-2(1H)-naphthalenone in 250 ml. of ethanol was added over a period of 30 min. 5 g. of sodium borohydride. After standing an additional 30 min., most of the ethanol was evaporated *in vacuo*, the residue diluted with water and extracted with ether. Evaporation to dryness gave 25 g. of the crude alcohol. This was dissolved in 50 ml. of pyridine and to it was gradually added with cooling 45 g. of *p*-toluenesulfonylchloride. After standing at room temperature for 2 hr., the mixture was poured into ice–water. The crystalline tosylate was recrystallized from ethyl acetate–ether, m.p. 81–83°; yield 29 g.

Anal. Calcd. for $C_{17}H_{18}O_3S$: C, 67.54; H, 6.00. Found: C, 67.31; H, 6.10.

A mixture of 10 g. of the tosylate and 5.3 g. of anhydrous hydrazine in 15 ml. of ethanol was refluxed for 6 hr. The alcohol was evaporated *in vacuo* and the residue taken up in a minimum of water. The addition of concentrated hydrochloric acid salted out VIII as its *p*-toluenesulfonic acid salt. After three recrystallizations from ethanol it melted at 151–153°.

Anal. Calcd. for $C_{10}H_{14}N_2 \cdot C_7H_8O_3S$: C, 61.06; H, 6.63; N, 8.38. Found: C, 60.99; H, 6.77; N, 8.37.

1-Indanylhydrazine (IXa).—A mixture of 50 g. of 1-indanone, 59.5 g. of hydrazine hydrochloride, and 1.0 g. of platinum oxide in 500 ml. of ethanol–water (4:1) was hydrogenated at 1000 p.s.i. at room temperature. After 2 hr. hydrogen uptake was complete. The alcohol and most of the water was evporated *in vacuo*. The residue was made basic with 50% potassium hydroxide and extracted several times with ether. The ether was dried and evaporated to dryness yielding 9 g. of the hydrazine from which the oxalate was made by addition of a saturated solution of oxalic acid in ethanol to a concentrated ethanolic solution of the base. The oxalate was recrystallized from ethanol–water, m.p. 187–189° dec.

Anal. Calcd. for $C_9H_{12}N_2 \cdot C_2H_2O_4$: N, 11.76. Found: N, 11.41.

Acid Fragmentation of 1-Acetyl-2-(1-indanyl)hydrazine (IXb).—A mixture of 13.2 g. of 1-indanone and 7.4 g. of acetylhydrazine was refluxed in 50 ml. of ethanol for 2 hr. Upon cooling, the hydrazone was collected and recrystallized twice from ethanol; yield 12 g., m.p. 175–177°.

Anal. Calcd. for $C_{11}H_{12}N_2O$: C, 70.18; H, 6.43; N, 14.88. Found: C, 69.70; H, 6.45; N, 15.06.

Five grams of the hydrazone in 50 ml. of glacial acetic acid was hydrogenerated over 0.12 g. platinum oxide at 40 p.s.i. One molar equivalent of hydrogen was absorbed in 1.5 hr. The catalyst was filtered and the solvent removed *in vacuo*. The residue was dissolved in water and made basic with ammonia. On cooling in the icebox the acetylhydrazine (IXb) crystallized. It was recrystallized from ethanol, m.p. 83–85°.

Anal. Calcd. for $C_{11}H_{14}N_2O$: C, 69.44; H, 7.42; N, 14.73. Found: C, 69.42; H, 7.49; N, 15.07.

Five grams of IXb was refluxed with 25 ml. of 6 *N* hydrochloric acid for 6 hr. under nitrogen. On cooling, crystalline hydrazine dihydrochloride separated. Extraction of the suspension with ether removed the hydrocarbon fraction. The ether was evaporated leaving a residue of 3 g. of crude indene, together with undoubtedly some dimer and polymer. The indene was characterized by conversion of a portion to 1-*p*-anisylideneindene (m.p. 118–119°) as directed by Weizmann[16] which showed no depression of melting point when mixed with an authentic sample.

The acid suspension remaining after extraction with ether was filtered giving 1 g. of hydrazine dihydrochloride, m.p. 195–197°.

Anal. Calcd. for $H_4N_2 \cdot 2HCl$: N, 26.67; Cl, 67.62. Found: N, 26.41; Cl, 66.96.

1,1-Dimethyl-1-(1-indanyl)hydrazonium Chloride (X).—To a solution of 12 g. of 1-chloroindane in 50 ml. of ethanol was added 18.9 g. of dimethylhydrazine. After standing at

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room temperature overnight, the ethanol was concentrated *in vacuo* and the residue recrystallized from ethanol, m.p. 175–178°.

Anal. Calcd. for $C_{11}H_{17}ClN_2$: C, 62.12; H, 8.00; N, 13.13. Found: C, 61.57; H, 8.08; N, 13.23.

That the reaction of a 1,1-dialkylhydrazine with an alkyl halide gives the quaternary compound rather than a 1,1,2-trialkylhydrazine has been amply demonstrated before. For a review of hydrazonium compounds see Sisler, *et al.*[17]

1,2,3,4-Tetrahydro-1-naphthylhydrazine.—A mixture of 10 g. of 3,4-dihydro-1(2H)-naphthalenone and 10 g. of hydrazine hydrochloride in 100 ml. of ethanol was hydrogenated over Raney nickel and worked up as described for IXa. However, the *p*-toluenesulfonic acid salt of the hydrazine was prepared. It was recrystallized from ethanol-ethyl acetate, m.p. 154–156° dec.

Anal. Calcd. for $C_{10}H_{14}N_2 \cdot C_7H_8O_3S$: C, 61.06; H, 6.63; N, 8.38. Found: C, 60.72; H, 6.70; N, 8.83.

1,1-Dimethyl-1-(1-phenylethyl)hydrazonium Bromide.—A solution of 3.3 g. of 1-phenylethyl bromide and 6 ml. of dimethylhydrazine in 15 ml. of ethanol was allowed to stand overnight at room temperature. The alcohol was evaporated *in vacuo* and the residue recrystallized from ethanol-ether, m.p. 140–143°.

Anal. Calcd. for $C_{10}H_{17}BrN_2$: C, 48.98; H, 6.94; N, 11.43. Found: C, 49.37; H, 7.00; N, 11.29.

Comparative Study of the Stability of Benzylhydrazines.—An approximate measure of the ease of fragmentation of these compounds into the hydrazine and the olefin was obtained as follows: To 1 ml. of an aqueous solution of IXa (10 min.), X (0.5 min.), 1,2,3,4-tetrahydro-1-naphthylhydrazine (10 min)., 1,1-dimethyl-1-(1-phenylethyl)hydrazonium bromide (20 min.), 1-indaneamine (stable), and IIId (stable) was added 1 ml. of concentrated hydrochloric acid. The times were noted when separation of the insoluble hydrocarbons became readily noticeable. These are included in parentheses after the appropriate compound. The characteristic odor of indene was noted after acid treatment of IXa and X, of 1,2-dihydronaphthalene from 1,2,3,4-tetrahydro-1-naphthylhydrazine and of styrene from 1,1-dimethyl-1-(1-phenylethyl)hydrazonium bromide.

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Structural Effects and Reactivity in Guanylhydrazone Formation: Temperature Coefficients of Rate of Formation of Several Guanylhydrazones

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Rates of reaction of seven carbonyl compounds, of a variety of structural types, with aminoguanidine, $NH_2NHC(NH)NH_2$, have been determined at 25° and 50° in aqueous phosphate buffer of pH 7, using an iodometric method of analysis. Guanylhydrazone formation for all the compounds investigated is a second order reaction and reversible, except for furfural, under the experimental conditions of the investigation. Relative thermodynamic activation quantities were calculated from experimentally determined temperature coefficients of rate. A previously proposed correlation between the presumed rigidities of carbonyl compounds and corresponding entropies of activation was not observed. This agrees essentially with previous data for oxime formation and thiosemicarbazone formation but diverges from results established for semicarbazone formation and at least six other reaction systems. However, an excellent linear free energy relationship exists between the logarithms of specific rates of guanylhydrazone formation and the logarithms of specific rates of semicarbazone formation. This linear relationship strongly suggests the fundamental similarity of the two reaction systems.

In 1941 Price and Hammett[2] measured the temperature coefficients of rate of semicarbazone formation and found a parallelism between a presumed order of molecular rigidity, derived from logical structural considerations, and entropies of activation, which is demonstrated by the data in columns one and two of Table I. They suggest that the observed parallelism was general in nature and would apply with high probability to other carbonyl reaction systems. The parallelism found subsequent confirmation in the aldol condensation,[3] the acid-catalyzed hydration of olefins,[4] the heterogenously catalyzed hydrolysis of esters,[5] the reaction of methyl iodide with certain amines in nitrobenzene[6,7] and in thiosemicarbazone formation of several alkyl butyrophenones.[8] Fitzpatrick and Gettler[9] and Fiarman and Gettler[10] studied oxime formation and thiosemicarbazone formation, respectively, in an attempt to secure additional support for the Hammett parallelism and to determine its validity

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