Summary

The solubility of thallous iodate was measured at 25° in aqueous solutions of the sodium salt of alkane-α,ω-disulfonic acids with from one to fourteen carbons in the separating chain. The results were considered on the basis of the Debye–Hückel equation.

All of the above-mentioned salts functioned as bivalent compounds, despite the great separation of the sulfonate groups in the case of the latter members of the series.

The values for the mean effective ionic diameters were calculated for each salt of the series of the alkane-α,ω-disulfonates. These values increased with increasing chain length. However, this increase in effective size was equivalent to only 0.25 Å. for each additional CH_2 group in the chain.

The small increment in effective size due to the addition of a methylene group to the aliphatic chain, as well as the bivalency of the disulfonate ion, was accounted for on the assumption that the molecule bent in the presence of a positive ion, both negative groups of the disulfonate ion being attracted to the oppositely charged particle.

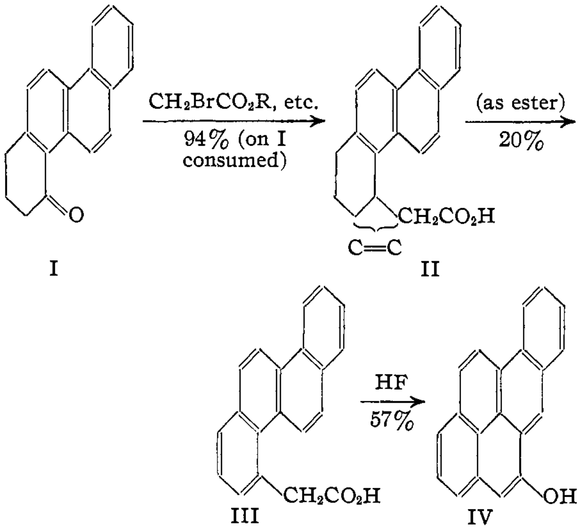
NEW YORK, N. Y. RECEIVED NOVEMBER 20, 1939

[CONTRIBUTION FROM THE CHEMICAL LABORATORY OF HARVARD UNIVERSITY]

Synthesis of 6-Hydroxy-3,4-benzpyrene and 8-Isopropyl-1,2-benzanthracene from 9,10-Dihydrophenanthrene

BY LOUIS F. FIESER AND WILLIAM S. JOHNSON

In extension of previous work[1] in which a satisfactory method was developed for obtaining 4-keto-1,2,3,4-tetrahydrochrysene (I) starting with 9,10-dihydrophenanthrene,[1b] this ketone has been utilized for the synthesis of the hitherto undescribed 6-hydroxy-3,4-benzpyrene (IV) by the process outlined.



The Reformatsky reaction at first seemed unpromising because of the separation of an insoluble complex which stopped the reaction. While no way was found for pushing the reaction to completion, it proved quite satisfactory to operate under mild conditions permitting the easy recovery of the unchanged starting material in a pure form after saponification of the ester. After dehydration with formic acid, the crude acidic product, possibly consisting of a mixture of isomers, was esterified and the ester dehydrogenated with sulfur, which gave better results than palladium charcoal. The product was contaminated with a small amount of high melting material which appeared to be a hydrocarbon, but this was separated easily after saponification of the ester.

Cyclization of 4-chryseneacetic acid (III) proceeded well under the influence of anhydrous hydrogen fluoride[2] giving pure 6-hydroxy-3,4-benzpyrene (IV) in good yield. It seemed interesting to determine whether an intermediate ketone could be detected, for in the formation of anthrones by cyclization, the use of hydrogen fluoride provides a particularly advantageous means of isolating the material in the ketonic condition and avoiding enolization. Even with highly sensitive anthrones which have not been isolated as such, it has been possible to effect a Grignard addition by adding the reagent directly to the crude residue remaining after evaporation of the hydrogen fluoride.[2b,3] This technique was applied in the present case and the mixture examined care-

---

[1] Fieser and Johnson, (a) THIS JOURNAL, **61**, 168 (1939); (b) *ibid.*, **61**, 1647 (1939).

[2] Fieser and Hershberg, (a) *ibid.*, **61**, 1272 (1939); (b) **62**, 49 (1940).

[3] Fieser and Cason, *ibid.*, **62**, 432 (1940).

fully for the presence of a carbinol or hydrocarbon. Aside from a trace of fluorescent material, no such product was found and it is concluded that the intermediate has no appreciable stability in the ketonic form.

Another series of synthetic experiments afforded 8-isopropyl-1,2-benzanthracene, desired as a further member of the series described[1] and for comparison with the carcinogenic 6-isopropyl compound[4] and with the 7[4]-(inactive) and 5[5]-isomers. The 8-keto-3,4,5,6,7,8-hexahydro-1,2-benzanthracene required as starting material was obtained from γ-(9,10-dihydro-2-phenanthryl)-butyric acid by cyclization with hydrogen fluoride in 89.5% yield (pure). A careful investigation of other cyclization methods was previously reported[1a] and the yields of pure ketone may be summarized for comparison: 85% sulfuric acid, 22%; zinc chloride and acetic acid-anhydride, 45%; phosphorus pentachloride-aluminum chloride, 63.5%. The ketone reacted satisfactorily with isopropylmagnesium bromide, giving after dehydration a hydrocarbon mixture which was dehydrogenated successfully with sulfur at 250°. Pure 8-isopropyl-1,2-benzanthracene was isolated through the picrate in 35% yield in the dehydrogenation step. It has been observed that an isopropyl group is eliminated from the 5[6]- and 10[7]-positions in dehydrogenations conducted with selenium but that a 10-isopropyl[7] or a 4-methyl[8] group can be retained at least in part by the use of sulfur.

Experimental Part[9]

4-Chryseneacetic Acid (III).—The Reformatsky condensation of methyl bromoacetate with 4-keto-1,2,3,4-tetrahydrochrysene[1b] (I) under a variety of conditions was subject to the difficulty that a sparingly soluble zinc complex separated as an oil which coated the zinc and stopped the reaction. Expedients tried with little success included vigorous stirring, the use of various special solvents, and suspension of the zinc in a basket to keep it away from the walls of the vessel. After numerous trials it was found most satisfactory to allow the reaction to proceed to a stopping point under moderate conditions and work up the mixture in such a way as to recover unchanged starting material in a pure condition.

Highly active metal for the reaction was prepared by immersing 30-mesh zinc in hot (100°) concentrated sulfuric acid containing a few drops of concentrated nitric acid. There was little evident reaction except that after about fifteen minutes the zinc surface became very bright. The acid was largely decanted and water added; a vigorous reaction with the dilute acid was allowed to proceed for a few minutes and the metal was then collected, washed thoroughly with water and then with acetone, and dried.

In a typical run 4 g. of activated zinc was added to a solution of 2 g. of the ketone (I) and 1.2 cc. of methyl bromoacetate in 40 cc. of dry benzene. The mixture was heated in a water-bath almost to boiling and a crystal of iodine was introduced, when the reaction promptly started and soon became vigorous. After heating for one hour the zinc had become completely coated over with oily complex, the mixture was cooled, enough methanol was added to dissolve the oil, and the solution was decanted from the metal, shaken with 10% hydrochloric acid, water, and saturated salt solution, and filtered through sodium sulfate. After removal of the solvent, the residual oil was boiled for fifteen minutes with excess 1 *N* alcoholic potassium hydroxide; water was added to the hot solution to the point of incipient cloudiness and on cooling 1.0 g. of unchanged ketone of good quality crystallized. Acidification of the alkaline liquor brought down a dark amorphous product which lost no weight when heated with anhydrous formic acid and which therefore was already in a dehydrated condition; yield 1.1 g. (94%, based on ketone consumed).

A solution of 1.7 g. of the crude acid in 250 cc. of methanol was saturated in the cold with hydrogen chloride, refluxed for twelve hours, diluted and extracted with ether. Vacuum distillation gave 1.44 g. of the ester as a yellow oil; this was heated with 0.18 g. of sulfur for two hours at 210°, and after heating with a pinch of zinc dust for five minutes, the product was distilled in vacuum. The distillate was dissolved in hot acetone–methanol and the solution filtered from about 80 mg. of high melting, unsaponifiable material (chrysene?). On cooling, 0.59 g. of product separated as glistening prisms (m. p. 109–111°) consisting of methyl 4-chryseneacetate contaminated with some of the above by-product. This was readily removed after saponification with 0.22 g. of potassium hydroxide in 7 cc. of boiling alcohol. The potassium salt of the chryseneacetic acid separated on cooling as glistening blades and was obtained colorless by washing with acetone. The salt dissolved readily in water and after filtration from a trace of the high-melting solid 4-chryseneacetic acid was precipitated in a high state of purity, m. p. 206.5–207.5°; yield 0.34 g. (20.1%, based on the crude unsaturated acid). A sample, crystallized once from benzene–acetone, formed colorless needles, m. p. 207–208°.

Anal.[10] Calcd. for $C_{20}H_{14}O_2$: C, 83.89; H, 4.93. Found: C, 84.12; H, 5.00.

From a number of variations tried in the dehydrogenation step it appeared that the reaction with sulfur proceeded better at the temperature specified than at higher or lower temperatures. With palladium charcoal the higher temperature required seemed to favor the formation of the high melting by-product and the yield was lower.

6-Hydroxy-3,4-benzpyrene (IV).—The following experiment was designed to detect any ketonic material

---

[4] Cook, *J. Chem. Soc.*, 456 (1932).

[5] Cook and de Worms, *ibid.*, 268 (1939).

[6] Cook, *ibid.*, 1592 (1933).

[7] Fieser and Hershberg, THIS JOURNAL, **59**, 1028, 2331 (1937).

[8] Fieser and Jones, *ibid.*, **60**, 1940 (1938).

[9] All melting points are corrected.

[10] Microanalysis by Herbert S. Wight.

resulting from the cyclization of 4-chryseneacetic acid. Three-tenths gram of the acid was treated with 20 g. of chilled liquid hydrogen fluoride in a platinum cylinder and after thirty minutes the excess reagent was removed in a stream of air and the chilled residue was treated with the Grignard reagent from 1.5 g. of magnesium and excess methyl chloride. After three hours the mixture was worked up as usual, giving a yellow, highly fluorescent ethereal solution. Evaporation left a solid residue which was sublimed at 150–155° and 0.001 mm. Sublimation occurred rapidly at first and then stopped, apparently because of encrustation of the residual solid, but after dissolving this in ether and evaporating to dryness, a further sublimate was obtained. The operation was repeated once more and the combined sublimate was crystallized from toluene, giving 0.16 g. (57%) of light yellow needles, m. p. 193–194°, decompn. Recrystallization raised the m. p. to 195–196°, decompn.

Anal.[10] Calcd. for $C_{20}H_{12}O$: C, 89.53; H, 4.51. Found: C, 89.12; H, 4.56.

The substance couples readily with diazotized *p*-nitroaniline to give a sparingly soluble, red azo compound. Like 4′-hydroxy-3,4-benzpyrene,[11] the phenol gives a red color in concentrated sulfuric acid and on adding a drop of concentrated nitric acid the solution acquires a transient green color changing to deep blue.

In search of a possible hydrocarbon the mother liquors were combined with the residue from the sublimation and submitted to chromatographic adsorption, but only a trace of fluorescent material could be washed through the tower with benzene and this was not identified.

8-Keto-3,4,5,6,7,8-hexahydro-1,2-benzanthracene.—γ-(9,10-Dihydro-2-phenanthryl)-butyric acid (7.1 g.) was treated with hydrogen fluoride (100 g.) at room temperature for two hours, the reagent was largely removed with a stream of air and the residue neutralized with sodium carbonate solution and extracted with benzene. No unchanged acid was detected and distillation in vacuum gave 6.2 g. (94%) of nearly colorless ketone. One crystallization from ligroin yielded 5.92 g. (89.5%) of colorless prisms, m. p. 89.5–90.5°, remelting at 96.5–97.5° (see ref. 1a).

8-Isopropyl-1,2-benzanthracene.—A benzene solution of 3 g. of the above ketone was added to a stirred solution of the Grignard reagent from 3 g. of magnesium and 15 g. of isopropyl bromide (transient red color). After refluxing for two hours and standing overnight, the product was worked up in the usual way and heated at 220° for several minutes to effect dehydration and distilled in vacuum from a small amount of high boiling residue. The pale yellow distillate (2.56 g.) when treated with petroleum ether gave 0.73 g. of crystallizate, consisting of pure starting ketone. The hydrocarbon fraction recovered from the mother liquor was an oil amounting to 1.83 g. (73.5%, based on ketone consumed). A mixture of 1.47 g. of the crude material and 0.34 g. of sulfur was heated at 205–250° for forty-five minutes, when the evolution of hydrogen sulfide had practically ceased, heated with a pinch of zinc dust, and distilled. The distillate, which partially solidified, was clarified by passage through an alumina tower in benzene solution and treated with 1.5 g. of picric acid in alcohol solution. One recrystallization from alcohol gave 0.94 g. (35%) of the picrate as shiny red blades, m. p. 151–153°. After three recrystallizations, a sample melted at 155.5–156.5°.

Anal.[12] Calcd. for $C_{21}H_{18}\cdot C_6H_3O_7N_3$: N, 8.41. Found: N, 8.38.

·Filtration of a benzene solution of 0.6 g. of the picrate through an alumina tower gave a yellow solution fluorescent in ultraviolet light. Crystallization of the hydrocarbon from alcohol gave 0.27 g. (83.5%) of glistening yellow prisms, m. p. 95–97.5°. Recrystallized from petroleum ether, the compound melted at 97–98°.

Anal.[12] Calcd. for $C_{21}H_{18}$: C, 93.29; H, 6.71. Found: C, 93.32; H, 6.74.

Summary

4-Keto-1,2,3,4-tetrahydrochrysene has been converted by Reformatsky reaction and dehydrogenation into 4-chryseneacetic acid and the latter cyclized with hydrogen fluoride to 6-hydroxy-3,4-benzpyrene.

8-Isopropyl-1,2-benzanthracene was synthesized by a process requiring a dehydrogenation in the last step; this was accomplished successfully with sulfur without loss of the alkyl group.

CONVERSE MEMORIAL LABORATORY
CAMBRIDGE, MASSACHUSETTS

RECEIVED JANUARY 20, 1940

---

[11] Fieser, Hershberg and Newman, THIS JOURNAL, **57**, 1509 (1935).

[12] Microanalysis by Lyon Southworth.