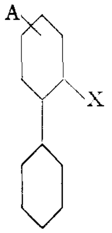
[CONTRIBUTION FROM THE CHEMICAL LABORATORY OF DUKE UNIVERSITY]

Aromatic Cyclodehydration. XXV.[1] 9-*p*-(Hydroxyphenyl)-10-alkylphenanthrenes

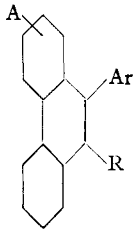
BY CHARLES K. BRADSHER AND WINSTON J. JACKSON, JR.[2]

It was found that α-(2-biphenylyl)-4-methoxypropiophenone and -butyrophenone may be cyclized to yield the expected 9-(*p*-hydroxyphenyl)-10-alkylphenanthrenes. Of the three methods tried, the most satisfactory for the synthesis of α-(2-biphenylyl)-4-methoxybutyrophenone involved the alkylation of 2-(biphenylyl)-acetonitrile followed by treatment with *p*-methoxyphenylmagnesium bromide.

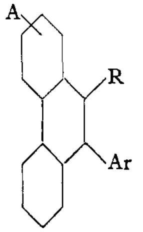
In an earlier communication,[3] it was shown that biphenyl derivatives of type I may be used as starting materials for the synthesis of substituted 9-alkyl-10-arylphenanthrenes (II). The purpose of the present work was to find a method which might be suitable for the conversion of similar biphenyl derivatives (I) to substituted 9-aryl-10-alkylphenanthrenes (III).



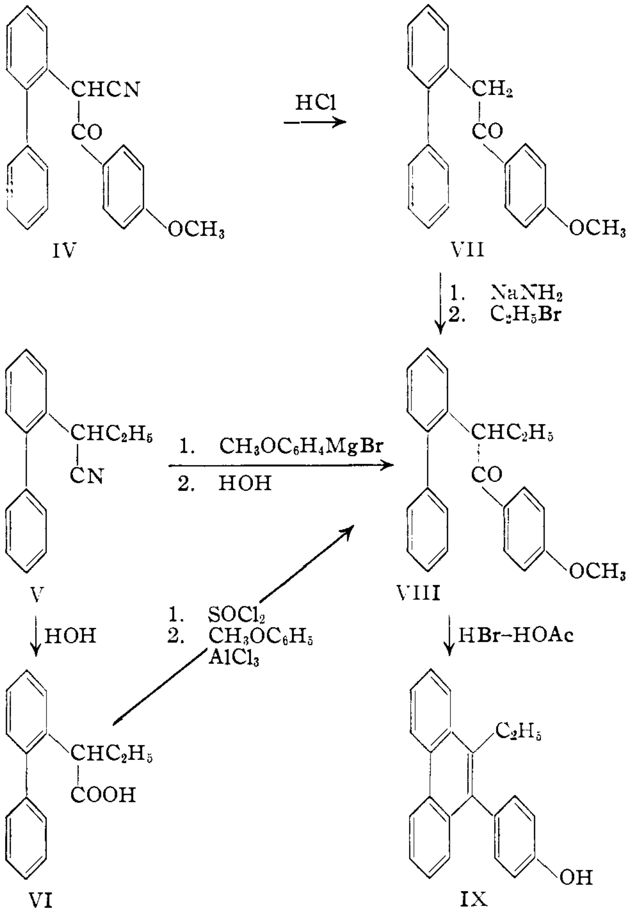
I



II



III



For our model experiments, we have studied the synthesis of 9-(*p*-hydroxyphenyl)-10-alkylphenanthrenes, starting from (2-biphenylyl)-acetonitrile (I, A = H, X = CH_2CN). The product (IV), obtained by acylation of the nitrile with ethyl anisate was shown earlier[4] to yield 9-(*p*-hydroxyphenyl)-phenanthrene in the hydrobromic–acetic acid cyclization. It seemed[4] reasonable to assume that the over-all reaction involved hydrolysis of the nitrile group followed by decarboxylation of the keto acid and cyclization of the resulting ketone (VII).

By use of a hydrochloric and acetic acid mixture, a less potent cyclizing medium, it has been possible to halt the reaction effectively at the ketone stage. In addition to the ketone (79% yield), a small quantity of 9-(*p*-methoxyphenyl)-phenanthrene was obtained. The new ketone (VII) was converted to the anion by the action of sodium amide, and then alkylated by use of either ethyl bromide (45% yield) or methyl iodide (54% yield). Cyclization of the α-(2-biphenylyl)-4-methoxybutyrophenone (VIII) afforded 9-(*p*-hydroxyphenyl)-10-ethylphenanthrene (IX) in 82% yield. The homologous ketone was converted in the same manner to 9-(*p*-hydroxyphenyl)-10-methylphenanthrene. The ultraviolet absorption spectra of the two phenanthrene derivatives (Fig. 1) are similar to each other and to that of 9-(*p*-methoxyphenyl)-phenanthrene.[4]

As an alternate approach to the synthesis of the alkylated ketone (VIII), (2-biphenylyl)-acetonitrile was alkylated with ethyl bromide (72% yield) and the product (V) converted in 64% yield to the ketone (VIII) by the action of *p*-methoxyphenylmagnesium bromide. The over-all yield of the ketone (VIII) from (2-biphenylyl)-acetonitrile, by this method, was 46%, while, by the ketonitrile route, it was only 20%. The action of Grignard reagents on alkylated nitriles of type V appears to be a promising method, not only for the synthesis of those ketones which yield 9-aryl-10-alkylphenanthrenes, but also for those which yield 9,10-dialkylphenanthrenes.

Hydrolysis of α-(2-biphenylyl)-butyronitrile (V) gave the corresponding acid (VI), which was converted to the acid chloride and allowed to undergo a Friedel and Crafts reaction with anisole. Only a small quantity of the expected ketone (VIII) was obtained.

Experimental[5]

Absorption Spectra.—The ultraviolet absorption spectra

---

[1] For the preceding communication of this series see C. K. Bradsher and R. S. Kittila, *J. Org. Chem.*, **15**, 374 (1950).

[2] Public Health Service Fellow, 1950–1951.

[3] C. K. Bradsher and L. J. Wissow, THIS JOURNAL, **68**, 2149 (1946).

[4] C. K. Bradsher and R. S. Kittila, *ibid.*, **72**, 277 (1950).

[5] All analyses are by the Micro-Tech Laboratories, Skokie, Illinois.

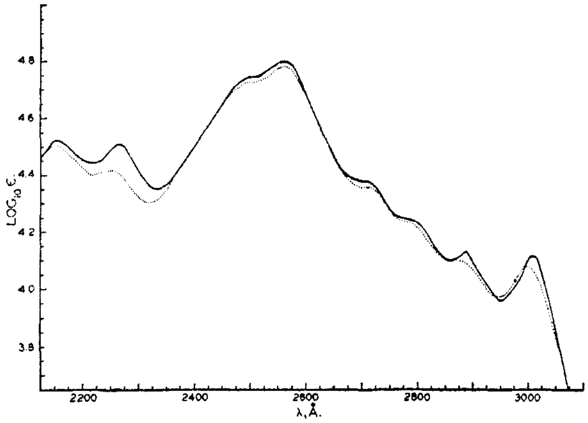


Fig. 1.—9-(*p*-Methoxyphenyl)-10-ethylphenanthrene, ———; 9-(*p*-methoxyphenyl)-10-methylphenanthrene, - - - - -.

were measured in 95% ethanol using a Beckman model DU quartz spectrophotometer. One centimeter silica cells were used in all measurements.

α-(**2-Biphenylyl**)-**butyronitrile** (V).—Sodium amide[6] was prepared in liquid ammonia from 2.6 g. of sodium and the ammonia displaced by 30 ml. of dry ether. To this suspension, 19.3 g. of (2-biphenylyl)-acetonitrile[4,7] in 30 ml. of dry ether was added and the mixture stirred and refluxed a half-hour. Next, 12 ml. of ethyl bromide was added very slowly (exothermic reaction), and the resulting mixture stirred at room temperature for 11 hours. At the end of this period, the mixture was poured on ice, acidified with cold dilute sulfuric acid, and extracted with ether. The ethereal extract was washed with water, dried, concentrated, and the residue was fractionated under reduced pressure. After a small forerun, the product was obtained as a yellow oil, b.p. 122–129° (1 mm.); yield 16 g. (72%). The analytical sample boiled at 129° (1 mm.); $n^{25}\text{D}$ 1.5704.

Anal. Calcd. for $C_{16}H_{15}N$: C, 86.84; H, 6.83. Found: C, 86.61; H, 6.78.

α-(**2-Biphenylyl**)-**butyric Acid** (VI).—To a solution containing 3.3 g. of the above nitrile (V) in 40 ml. of acetic acid, 30 ml. of 48% hydrobromic acid was added and the mixture refluxed for 37 hours. The mixture was diluted with water and extracted with ether. The ethereal extract was first washed with water and then extracted several times with sodium bicarbonate solution. Acidification of the bicarbonate extract yielded 2.5 g. (70%) of a product, m.p. 104–105°, from ether–petroleum ether.

Anal. Calcd. for $C_{16}H_{16}O_2$: C, 79.97; H, 6.71. Found: C, 80.00; H, 6.90.

ω-(**2-Biphenylyl**)-**4-methoxyacetophenone** (VII).—Ten grams of the α-(*p*-anisoyl)-*o*-phenylbenzyl cyanide[4] (IV) was refluxed for 72 hours in a mixture containing 125 ml. of acetic acid and 50 ml. of concentrated hydrochloric acid. On cooling, 0.8 g. (9%) of 9-(*p*-methoxyphenyl)-phenanthrene was formed, m.p. 151–154°. Once recrystallized from benzene, this did not depress the melting point of an authentic[4] sample, m.p. 156.5–157.5°.

The acid solution was diluted with water and extracted with methylene chloride. The methylene chloride solution was washed with water and bicarbonate solution, dried (sodium sulfate) and concentrated. The residue was fractionated under reduced pressure, yielding 7.4 g. (79%) of a very viscous yellow oil, b.p. 196–218° (0.5 mm.). This product, which was satisfactory for further reactions, contained a small quantity of 9-(*p*-methoxyphenyl)-phenanthrene. The analytical sample boiled at 218° (0.5 mm.); $n^{25}\text{D}$ 1.6355.

Anal. Calcd. for $C_{21}H_{18}O_2$: C, 83.42; H, 6.00. Found: C, 83.25; H, 5.97.

α-(**2-Biphenylyl**)-**4-methoxybutyrophenone** (VIII) (a) **By Alkylation of** ω-(**2-Biphenylyl**)-**4-methoxyacetophenone** (VII).—Sodium amide was prepared in liquid ammonia using 0.64 g. of sodium. The excess ammonia was displaced by 40 ml. of dry ether. To the resulting suspension, 6.9 g. of the ketone (VII) in 30 ml. of dry ether was added. After the mixture had been stirred and refluxed for one-half hour, 15 ml. of ethyl bromide was added slowly. Stirring and refluxing were continued for 18 hours, after which the mixture was poured into ice-water and acidified with cold dilute sulfuric acid. The product was taken up in ether and the ethereal solution was washed, dried, treated with Norite and concentrated. The residue was crystallized from ethanol as white granular crystals, m.p. 116–119°; yield 3.4 g. (45%). On recrystallization, the product melted at 119–120°.

(b) **From** α-(**2-Biphenylyl**)-**butyronitrile** (V) **by the Grignard Reaction**.—To a Grignard reagent prepared from 5.8 g. of *p*-bromoanisole, 2.2 g. of α-(2-biphenylyl)-butyronitrile (V) in 15 ml. of dry ether was added. The mixture was refluxed for six hours and then allowed to stand overnight. It was decomposed by addition of 2 *N* hydrochloric acid, the ether was removed by distillation, and the residual crude imine and acid were heated for one-half hour on the steam-bath, with stirring. The resulting oil was extracted with methylene chloride and the extracts were washed with water, dried, treated with Norite, and concentrated. The residue was dissolved in 250 ml. of boiling alcohol and filtered from the unidentified flocculent material (about 0.1 g.) which deposited on cooling. On concentration of the filtrate, 2.1 g. of brown crystals, m.p. 115–118°, was obtained. Recrystallization from ethanol produced white granular crystals, m.p. 119–120°.

(c) **From** α-(**2-Biphenylyl**)-**butyryl Chloride by the Friedel and Crafts Reaction**.—The α-(2-biphenylyl)-butyric acid (VI, 0.90 g.) was refluxed for one-half hour with 8 ml. of thionyl chloride, and the excess thionyl chloride was removed under reduced pressure. The residue was dissolved in 20 ml. of redistilled anisole and the mixture cooled in an ice-bath while 0.5 g. of aluminum chloride was added. The mixture was stirred and cooled for five hours, after which the cooling bath was removed and stirring was continued for an additional 12 hours. The mixture was decomposed with ice, the excess anisole steam distilled, and the residue was taken up in methylene chloride. The extracts were washed with water and dried. The solvent was removed and the residue twice recrystallized from ethanol, m.p. 118–119.5°; yield 0.06 g. (5%). After one more recrystallization, the compound melted at 119–120°.

Mixed melting points of products obtained by all three procedures showed no depression of melting point.

Anal. Calcd. for $C_{23}H_{22}O_2$: C, 83.60; H, 6.71. Found: C, 83.64; H, 6.60.

9-(*p*-Hydroxyphenyl)-10-ethylphenanthrene (IX).—To 1.0 g. of the alkylated ketone (VIII) dissolved in 20 ml. of acetic acid, 10 ml. of 48% hydrobromic acid was added and the mixture was refluxed for 48 hours. Subsequently, the mixture was diluted and was extracted with methylene chloride. The extract was washed to remove the acids and then dried and concentrated. The residue crystallized from benzene (Norite) as light tan needles, m.p. 199.5–201.5°; yield 0.73 g. (82%). The analytical sample crystallized from benzene as white needles, m.p. 201–201.5°.

Anal. Calcd. for $C_{22}H_{18}O$: C, 88.56; H, 6.08. Found: C, 88.71; H, 6.18.

The methyl ether was prepared in 98% yield by the action of dimethyl sulfate on an alkaline solution of the phenol (IX). The analytical sample crystallized from ligroin as clusters of stout white needles, m.p. 156.5–157.5°.

Anal. Calcd. for $C_{23}H_{20}O$: C, 88.42; H, 6.45. Found: C, 88.60; H, 6.45.

The acetate was prepared by refluxing the phenol (IX) with acetic anhydride and pyridine. The product crystallized from acetic acid to yield colorless plates, m.p. 181–181.5°.

Anal. Calcd. for $C_{24}H_{20}O_2$: C, 84.68; H, 5.92. Found: C, 84.60; H, 6.14.

α-(**2-Biphenylyl**)-**4-methoxypropiophenone**.—ω-(2-Biphenylyl)-4-methoxyacetophenone (VII, 6 g.) was treated with sodium amide as in the preparation of α-(2-biphenylyl)-4-methoxybutyrophenone (VIII), but then treated with methyl iodide instead of ethyl bromide. The reaction mixture was worked up as before, and the product was recrystallized from ether as white cubes, m.p. 135.5–137.5°; yield 3.4 g. (54%). The analytical sample melted at 137.5–138.5°.

---

(6) R. Levine and C. R. Hauser, THIS JOURNAL, **68**, 760 (1946).

(7) J. von Braun and G. Manz, *Ann.*, **468**, 258 (1929).

Anal. Calcd. for $C_{22}H_{20}O_2$: C, 83.51; H, 6.37. Found: C, 8.360; H, 6.54.

9-(*p*-Hydroxyphenyl)-10-methylphenanthrene.—The above ketone (2.3 g.) was refluxed for 18 hours with a mixture of hydrobromic and acetic acids and the reaction mixture was worked up as in the synthesis of the homolog (IX). The product crystallized from benzene–ligroin as clusters of white needles, m.p. 149–150.5°; yield 1.7 g. (82%). The analytical sample melted at 150.5–151°.

Anal. Calcd. for $C_{21}H_{16}O$: C, 88.70; H, 5.67. Found: C, 89.00; H, 5.89.

The methyl ether, prepared by the action of methyl sulfate, crystallized as colorless, parallelogram-shaped plates, m.p. 137–138°.

Anal. Calcd. for $C_{22}H_{18}O$: C, 88.56; H, 6.08. Found: C, 88.67; H, 6.22.

The acetate, prepared as in the case of the homolog, crystallized as colorless irregnlar plates, m.p. 158–158.5°.

Anal. Calcd. for $C_{23}H_{18}O_2$: C, 84.62; H, 5.56. Found: C, 84.58; H, 5.68.

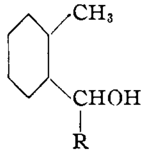
DURHAM, N. C. RECEIVED JANUARY 25, 1951

[CONTRIBUTION FROM THE DEPARTMENT OF CHEMISTRY, ILLINOIS INSTITUTE OF TECHNOLOGY]

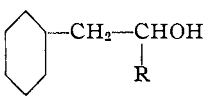
The Reaction of Benzylmagnesium Chloride with Aliphatic Aldehydes[1]

BY SAMUEL SIEGEL, WILLIAM M. BOYER AND RAYMOND R. JAY

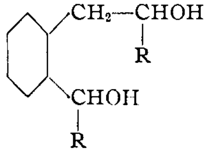
The reaction of benzylmagnesium chloride with seven aliphatic aldehydes was studied. Monomeric formaldehyde yields *o*-tolylcarbinol (I, R = H) but no 2-phenylethanol, which is in accord with the classical example of Tiffeneau and Delange[2] but contradicts the recent report of Mousseron and Du.[3] The latter claim that gaseous formaldehyde, or formaldehyde dissolved in ether, reacts to form II (R = H) but agree that polyoxymethylene yields I (R = H).



I



II



III

Acetaldehyde, propionaldehyde, *n*-butyraldehyde, *i*-butyraldehyde, 2-ethylhexaldehyde and *n*-heptaldehyde yield mixtures of compounds of types II and III but none of type I. The mole per cent. of "abnormal" product (III) formed is in the order of the aldehydes listed: 47, 64, 45, 15, 20 and 8. These results are consistent with the mechanism proposed previously for the reaction of citronellal with benzylmagnesium chloride.[4] The relation of structure of the aldehyde to the ratio of "abnormal" (III) to normal (I) products is explained in terms of the contributions of hyperconjugation and steric factors.

The classical example of the abnormal reaction of benzylmagnesium chloride is that with formaldehyde in which *o*-tolylcarbinol (I, R = H) is formed instead of the expected benzylcarbinol (II, R = H).[2] Other reactants such as acetyl chloride and chloromethyl ether give rise to *o*-tolyl derivatives as well as products which would normally be expected.[5,6] Benzaldehyde[7,8] and citronellal[4] appear to be unique in that compounds (III) resulting from the combination of two molecules of the aldehyde and one of the Grignard reagent are formed along with the normal product (II). In contrast to the behavior of these aldehydes, the reaction of acetaldehyde[9] with benzylmagnesium chloride is reported to yield only the normal product but this investigation was incomplete.[10] In an attempt to clarify this problem, the reaction of benzylmagnesium chloride with seven aliphatic aldehydes was studied including a reinvestigation of the reaction with monomolecular formaldehyde. With the exception of the latter, each aldehyde formed both normal products (II), and "abnormal" products of type (III), but no *o*-tolyl derivatives. Formaldehyde yielded *o*-tolylcarbinol. There was no evidence that a compound of type (II) was present.

Table I presents the yields of the products obtained under standardized conditions in which the aldehyde was added to the Grignard reagent. Addition of the Grignard reagent to the aldehyde has been shown to increase the per cent. of "abnormal" products.[4,7,8]

TABLE I

YIELDS OF PRODUCTS FROM THE REACTION OF BENZYLMAGNESIUM CHLORIDE WITH ALDEHYDES

Aldehyde	Theoretical yield, %	Mole per cent. abnormal product
Formaldehyde	40[a]	100
Acetaldehyde	61	47
Propionaldehyde	97	64
n-Butyraldehyde	73	45
i-Butyraldehyde	88	15
n-Heptaldehyde	69	20
2-Ethylhexaldehyde	72	8

[a] This yield is a minimum value based upon the quantity of polyoxymethylene used in preparing the monomeric formaldehyde.

Proceeding along the homologous series of straight chained aliphatic aldehydes beyond formaldehyde the yield of "abnormal" product (III) reaches a maximum with propionaldehyde. The yield decreases with increasing chain length and par-

---

[1] Presented before the Organic Division at the Chicago Meeting of the American Chemical Society, September 3–10, 1950.

[2] M. Tiffeneau and Delange, *Compt. rend.*, **137**, 573 (1903).

[3] M. Mousseron and N. P. Du, *Bull. soc. chim.*, [5] **15**, 91 (1948).

[4] W. G. Young and S. Siegel, THIS JOURNAL, **66**, 354 (1944).

[5] H. Gilman and J. E. Kirby, *ibid.*, **54**, 345 (1932).

[6] P. R. Austin and J. R. Johnson, *ibid.*, **54**, 647 (1932).

[7] J. Schmidlin and A. Garcia-Banùs, *Ber.*, **45**, 3193 (1912).

[8] S. Siegel, S. K. Coburn and D. R. Levering, THIS JOURNAL, **73**, 3164 (1951).

[9] F. C. Whitmore and T. K. Sloat, *ibid.*, **64**, 2968 (1942).

[10] J. R. Johnson, *ibid.*, **55**, 3029 (1933) in a footnote referred to . . . "unpublished work of Mr. L. G. Davy shows that acetaldehyde and *n*-butyraldehyde induce the *o*-tolyl rearrangement to an appreciable extent." To our knowledge nothing more has appeared on this matter.