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Synthesis and Chemistry of Hexamethyl-*trans*-15,16-dihydropyrene[1a]

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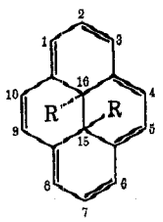
A seven-step synthesis of hexamethyl-*trans*-15,16-dihydropyrene is described. The dark green hydrocarbon possesses spectra and physical properties characteristic of this 14-π-electron system. It easily undergoes electrophilic substitution reactions yielding 2- and 4-mono- and 2,7-disubstituted derivatives, with which further transformations have been accomplished.

The syntheses of *trans*-15,16-dimethyl-[2] and *trans*-15,16-diethyldihydropyrene[3] by Boekelheide,[2,3] Phillips,[2] and Miyasaka[3] constitute a very interesting test of the Hückel theory of aromaticity. These unique molecules (**1**, R = CH_3 or C_2H_5) bear substituents



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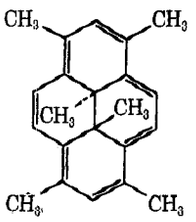

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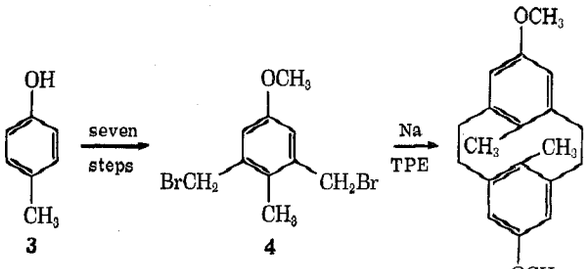
which are contained completely within the cavity generated by the planar 14-π-electron periphery. The physical and chemical properties of these molecules provide strong support for the Hückel theory, which predicts that $(4n \pm 2)$ π electrons of an aromatic ring form a doughnut-shaped cloud above and below the plane of the ring. The center of such a π cloud then might be empty space, and these molecules present a special opportunity to examine the effect of substituent groups within a π-electron system on the π cloud, and vice versa.

An investigation conducted in our laboratory has produced 1,3,6,8,15,16-hexamethyl-*trans*-15,16-dihydropyrene (**2**), the synthesis, physical properties, and chemistry of which we would now like to record.

The synthesis of *trans*-15,16-dimethyldihydropyrene began with *p*-cresol (**3**) and required seven steps to effect the placement of bromomethyl groups adjacent to the methyl group of **4**, a necessary precursor for the Wurtz cyclization to the corresponding [2.2]metacyclophane (**5**).[2] Although this route is necessary for the



3 **4** **5**

construction of the desired metacyclophane, and consequently for dimethyldihydropyrene, shorter approaches for the preparation of other dihydropyrenes could be foreseen. In this laboratory the need for a hexaalkyldihydropyrene prompted the use of mesitol (**6**, Chart I) as starting material for the synthesis of **2**. From a synthetic viewpoint, the presence of alkyl groups adjacent to the more strongly orienting hydroxyl function of **6** fortunately allowed direct introduction of halomethyl substituents, *e.g.*, *via* a chloromethylation procedure. Accordingly, our synthesis of the resultant hexamethyl-*trans*-15,16-dihydropyrene is shown in Chart I.

Mesitol (**6**) was converted to methoxymesitylene (**7**) which was chloromethylated[4] to the bis(chloromethyl) compound **8** in good yield. Transformation of **8** into hexamethyl 5,13-dimethoxy[2.2]metacyclo-

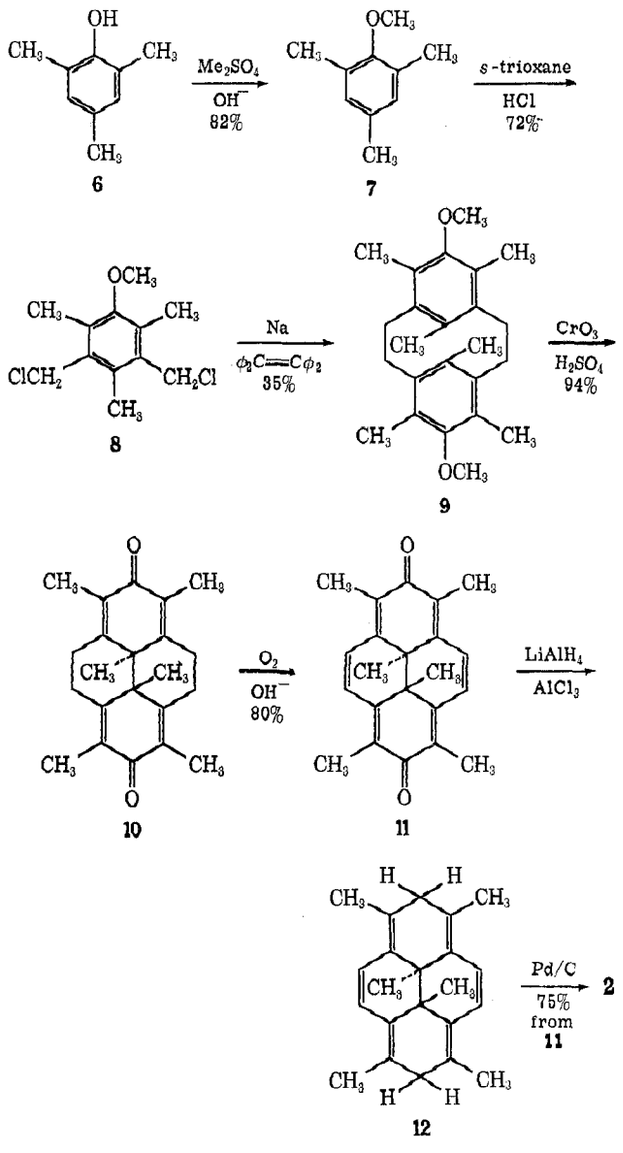
(1) (a) Presented in part at the 153rd National Meeting of the American Chemical Society, Miami Beach, Fla., April 1967, Paper O-184. (b) Original manuscript received February 26, 1968.

(2) V. Boekelheide and Joseph B. Phillips, *J. Amer. Chem. Soc.*, **89**, 1695 (1967).

(3) V. Boekelheide and T. Miyasaka, *ibid.*, **89**, 1709 (1967).

(4) J. von Braun and J. Nelles, *Chem. Ber.*, **67**, 1094 (1934).

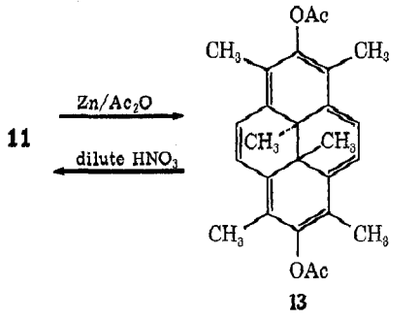
CHART I



phane[5] (**9**) was accomplished *via* a modified Wurtz procedure using a very fine sodium sand and tetraphenylethylene[6,7] as catalyst. The average yield for this step was 35%, which is higher than that reported previously for 8,16-substituted [2.2]metacyclophanes formed in a double bridge closure.[7] When the corresponding bis(iodomethyl)methoxymesitylene, prepared from **8** by halide exchange, was subjected to the same cyclization conditions, **9** was obtained only in 17% yield. Thus the use of the chloromethyl intermediate not only eliminates the necessity for a halide exchange step but also leads to a considerable improvement in the yield of metacyclophane. The nmr spectrum of this compound shows a six-proton singlet at τ 9.50, characteristic of the 8,16 internal methyl groups of [2.2]metacyclophanes.[7]

Oxidation of **9** gave the pale yellow hexamethylbis(dienone) (**10**),[8] the internal methyls of which appear in its nmr spectrum at τ 8.87. The downfield shift from τ 9.50 to 8.87 of the internal methyls is indicative of the change from the stepped *trans*-[2.2]metacyclophane structure to the more planar bis(dienone), where the internal methyl groups of **10** no longer protrude over the shielding face of the opposing aromatic ring.

Air oxidation of hexamethylbis(dienone) in ethanolic potassium hydroxide produces the stable bright orange hexamethyldihydropyrene-2,7-quinone (**11**) which is a true quinone as shown by its ready reduction to its dark green hydroquinone diacetate, 2,7-diacetoxyhexamethyldihydropyrene (**13**), which could be reoxidized



to the quinone by dilute nitric acid. The nmr spectrum of **13** is indicative of the strong ring current of the 15,16-dihydropyrenes,[2,3] whereas the lateral 4, 5, 9, and 10 protons are deshielded and appear as a singlet at τ 1.34 (as do the 1-, 3-, 6-, and 8-methyls which appear at τ 7.00); the internal 15- and 16-methyls are strongly shielded by the 14 π system which surrounds them and appear at τ 13.88.

The reduction of the quinone to the bis(triene) **12** at room temperature yields a 3:2 mixture of the desired hexamethyldihydropyrene **2** and the bis(triene) **12**. The ready formation of some hexamethyldihydropyrene directly in this reduction is a striking illustration of the driving force directed toward the formation of this stable 14-π-electron system. No attempt was made to separate the two products, but from the nmr spectrum of such a mixture (see Experimental Section) the resonances and therefore the relative amount of **12** could easily be determined.

Dehydrogenation of this mixture produced hexamethyl-*trans*-15,16-dihydropyrene (**2**); the overall yield in seven steps was 11%. The ultraviolet–visible absorption spectrum of the hydrocarbon, which crystallizes from heptane in large black-green prisms, mp 185–186°, is shown in Figure 1. The nmr spectrum of **2** shows dramatically the effect of a strong induced ring current. Whereas the internal methyl resonances are shifted to abnormally high field and appear as a singlet at τ 14.04, the peripheral methyl resonances appear at τ 6.84, and proton resonances appear at τ 2.20 for the 2 and 7 protons and at τ 1.44 for four lateral protons. The signals for these peripheral methyls and protons are significantly downfield from the usual regions for aromatic methyl and proton resonances.

(5) The numbering of [2.2]metacyclophanes used here is that suggested by B. H. Smith in "Bridged Aromatic Compounds," Academic Press, New York, N. Y., 1964, Chapter 1.

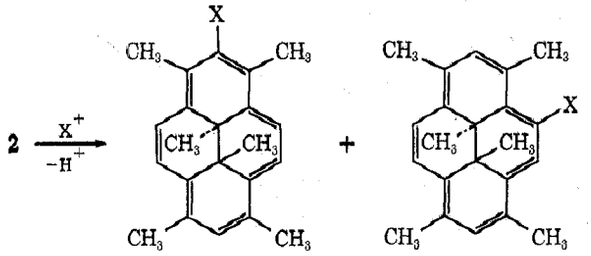
(6) E. Muller and G. Roscheisen, *Chem. Ber.*, **90**, 543 (1957).

(7) W. S. Lindsay, Peter Stokes, Leslie G. Humber, and V. Boekelheide, *J. Amer. Chem. Soc.*, **83**, 943 (1961).

(8) The transformation **9** → **10** was accomplished also with anhydrous ferric chloride in 10–15% yields.

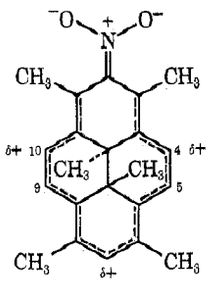
In addition to the strong ring current demonstrated by 15,16-dimethyldihydropyrene,[2] chemical evidence[9] for its aromatic character was indicated by its ease of electrophilic substitution to give numerous derivatives. Hexamethyldihydropyrene, similarly, will undergo such reactions.[10]

The electrophilic substitution of hexamethyldihydropyrene usually resulted in the formation of a mixture of 2- and 4-monosubstituted products, **14** and **15**, when 1 mol of the electrophile was employed.



14 **15**

Nitration of **2** with cupric nitrate in acetic anhydride[9,11] produces a 2:1 mixture of 2-nitro- (**14**) and 4-nitrohexamethyldihydropyrene (**15**). The 2-nitro isomer shows singlet resonances in its nmr spectrum at τ 1.24 for the 4, 5, 9, and 10 protons, τ 2.06 for the 7 proton, τ 6.83 and 6.92 for the 1,3- and 6,8-methyls, and two singlets separated by 30 Hz centered at τ 13.88 for the internal 15,16-methyls. It is of interest to observe the chemical equivalence of the 4 and 10 protons to the 5 and 9 protons. If the nitro group of **14** were conjugated to a great extent with the dihydropyrene ring, a resulting resonance hybrid like **16** would require the 4 and 10 protons to be equivalent and distinct from the equivalent 5 and 9 protons;



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consequently an AB-type spin system would be expected. That only a singlet is observed for these protons suggests that the nitro group is not interacting with the π system, but is in fact forced out of the plane of the ring by the flanking 1- and 3-methyls. Since **14** (X = NO_2) easily undergoes more extensive nitration to give polynitro products, there is no evidence of diminished reactivity toward further electrophilic attack, also indicative of a nonconjugated nitro group. This observation is in marked contrast to the formylation experiment described below.

(9) J. B. Phillips, R. J. Molyneux, E. Sturm, and V. Boekelheide, *J. Amer. Chem. Soc.*, **89**, 1704 (1967).

(10) Another measure of aromaticity is diamagnetic susceptibility. The diamagnetic anisotropy of **2** has been reported. See H. J. Dauben, J. D. Wilson, and John L. Laity, *J. Amer. Chem. Soc.*, **91**, 1991 (1969).

(11) A. G. Anderson, Jr., J. A. Nelson, and J. J. Tazuma, *ibid.*, **75**, 4980 (1953).

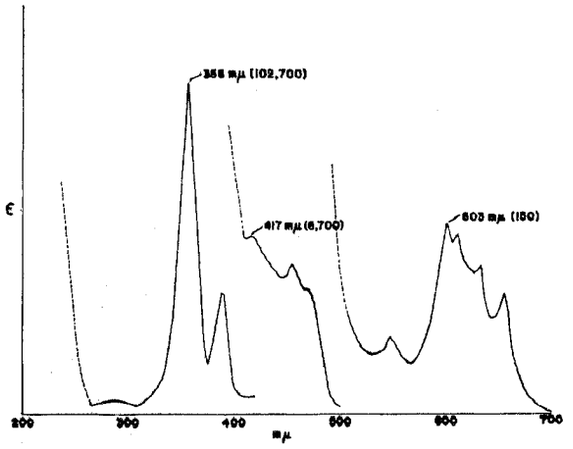
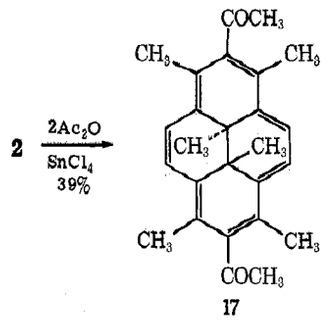


Figure 1.—Ultraviolet–visible absorption spectrum of hexamethyl-*trans*-15,16-dihydropyrene in hexane.

X-ray analysis of a dimethyldihydropyrene[12] has shown that the aromatic bond distances and bond angles are quite close to those of benzene. Therefore it should be expected that the effect of flanking 1,3-methyls in **16** would simulate that of 2,6-methyls on the steric inhibition of resonance in 1-substituted benzenes.[13]

Likewise, the nmr spectrum of the 4-nitro isomer indicates a lack of conjugation with the aromatic ring. A singlet resonance at τ 1.44 is assigned to the 9 and 10 protons in **15** (X = NO_2), which appear to be chemically equivalent. The internal methyls appear as two singlets centered at τ 13.68.

Acylation of **2** gives several products, depending upon the particular reaction. Acetylation[11] produced 2:1 mixtures from which the 2-acetyl isomer (**14**), what is believed to be the 4-acetyl isomer (**15**) that eluded exact characterization, and a trace of the 2,7-diacetylhexamethyldihydropyrene (**17**) could be isolated. All prod-



17

ucts retain the dark green dihydropyrene color. With two equivalents of acetic anhydride, **17** is the chief product. The infrared spectra of **14** (X = $COCH_3$) and **17** possess carbonyl bands at 1705 cm^{-1}, suggesting lack of conjugation of these acetyl groups with the aromatic ring. This is fully confirmed by the nmr spectrum of the 2-acetyl compound, which shows a singlet at τ 1.36, assigned to the nondifferentiated 4, 5, 9, and 10 protons. Also, the chemical reactivity of these compounds is undiminished toward further acetylation, indicating the lack of transmission by the acetyl group of

(12) A. W. Hanson, *Acta Crystallogr., Sect. B*, **18**, 599 (1965).

(13) Such steric effects in the aromatic substitution of benzenes are well documented. See, for example, G. S. Hammond and M. F. Hawthorne in "Steric Effects in Organic Chemistry," Melvin S. Newman, Ed., Wiley, New York, N. Y., 1956, Chapter 3.

any deactivating effect to the ring. As with the nitro compounds, this is due to its noncoplanar arrangement with the ring caused by the 1- and 3-methyl groups.

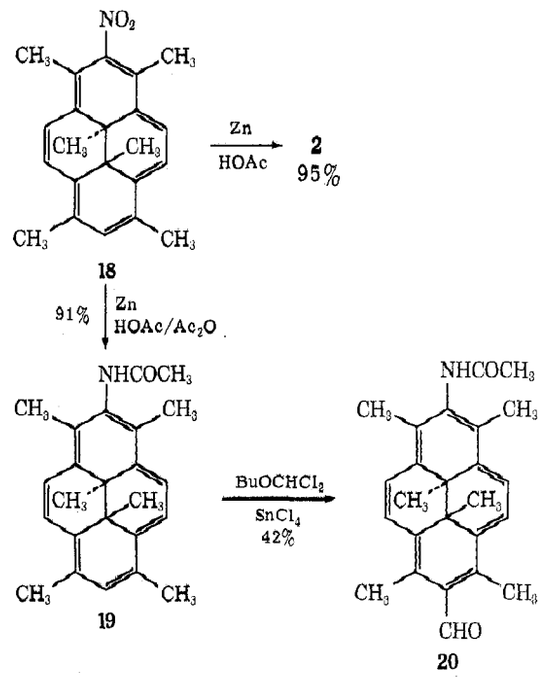
Formylation of **2** was accomplished smoothly and in excellent yield by means of the Rieche[9,14] procedure.

A mixture of 2-formyl- (**14**, X = CHO) and 4-formylhexamethyldihydropyrene (**15**, X = CHO) was obtained in 81 and 9% yields, respectively. Infrared spectra of these black-red substances show carbonyl frequencies at 1675 and 1656 cm^{-1}, respectively, indicating a strong conjugation of the formyl carbonyls with the dihydropyrene ring, a conclusion which is in complete agreement with the nmr spectra of these products, and the fact that they are inert toward further formylation under the same conditions in the presence of excess reagent. The nmr spectrum of the 2-formyl isomer shows two sharp singlets at τ 13.68 and 13.63 (the two internal methyls), singlets at τ 6.90 (the methyls at 6 and 8) and 6.65 (the methyls at 1 and 3), a singlet at τ 2.18 (the 7 hydrogen), a singlet at τ −1.36 (the formyl hydrogen), and an AB quartet, J = 8 Hz, centered at τ 1.33, clearly indicating strong coupling of the 4,10 protons with the 5,9 protons. The formyl group is apparently small enough to assume a coplanar arrangement with the dihydropyrene ring, in spite of the flanking 1,3-methyls.

The nmr spectrum of the 4-formyl isomer indicates the same degree of conjugation: two singlets at τ 2.26 and 2.18 are assigned to the 2 and 7 protons, and an AB quartet centered at τ 1.53 (J = 8 Hz) shows the coupling of the 9 and 10 protons. The proton at C-5 experiences additional deshielding due to its location adjacent to the formyl and appears at τ 0.82.

Halogenation of **2** using bromine occurred readily, yielding polybrominated products. With *N*-bromosuccinimide the reaction is much cleaner; mixtures of 2-bromo and 2,7-dibromo products result in good crude yields. The nmr spectrum of the 2-bromo compound (**14**, X = Br) shows singlet resonances at τ 13.88 for internal methyls, and an AB-type quartet centered at τ 1.32 (J = 8 Hz) for the 4, 5, 9, and 10 protons. However, the components of these mixtures are sufficiently similar in properties that their complete separation and rigorous identification have not been possible.

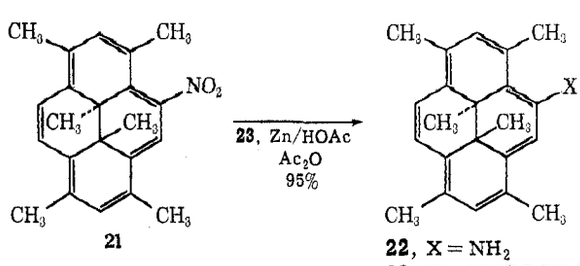
Various transformations of these electrophilically introduced substituents have been carried out. Reduction studies of the 2- and 4-nitrohexamethyldihydropyrenes were the first to be considered. Attempts to prepare 2-aminodimethyldihydropyrene[9] by reduction of the 2-nitro compound appeared to give the corresponding ammonium salt, but liberation of the free base resulted in its decomposition. It seems that strong electron-releasing substituents on the dihydropyrene ring produce an unstable or highly reactive molecule,[15] but in the hexamethyl series we anticipated that the amino group might be forced by the adjacent methyls into a more noncoplanar arrangement with the aromatic ring, with a resultant increase in stability of the molecule. However when **18** was treated with zinc in acetic acid, a rapid clean reduction to the parent hydrocarbon **2** occurred in 95% yield. This unusual reductive cleavage of an aromatic nitro group is apparently



an effect of the dihydropyrene ring and not a purely steric effect of the 1- and 3-methyls. Reduction of 2-nitromesitylene under the same conditions does not give mesitylene, while reduction in the presence of acetic anhydride gives a 70% yield of the expected 2-acetomesidide. Since, in the presence of acetic anhydride, the 2-acetamido derivative **19** is obtained in 91% yield, it would appear that 2-aminohexamethyldihydropyrene is present in some form in the course of the reduction.

An unsymmetrical disubstituted dihydropyrene **20** was prepared by formylation of **19** using the Rieche procedure.

Reduction of the 4-nitro isomer **21** appears to form the 4-amino compound **22**, but the rapidity of its decomposition prevented its isolation; the reductive removal of the nitro group to give **2** does not occur in this case. In the presence of acetic anhydride the corresponding 4-acetamido compound **23** is obtained in high yield.

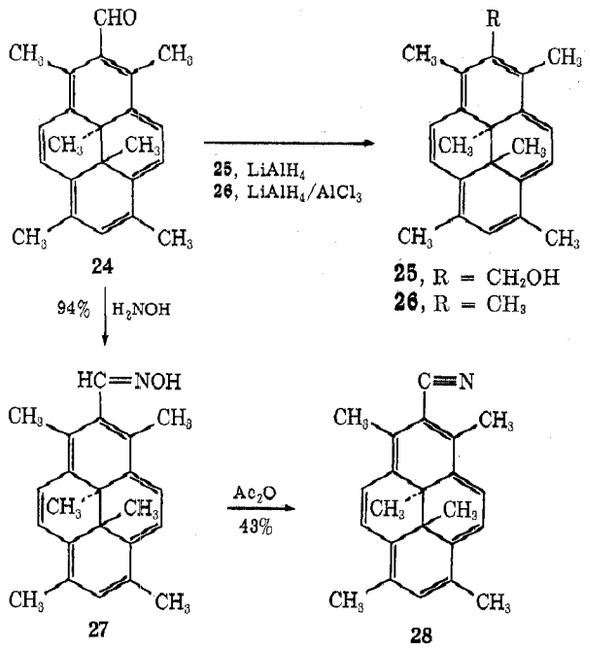


The 2-formyl derivative **24** could easily be reduced to the hydroxymethyl compound **25**, which in turn could be oxidized back to the aldehyde with manganese dioxide[16a] in quantitative yield. When the mixed hydride reducing reagent was employed, a quantitative reduction of **24** to the heptamethyldihydropyrene **26** resulted.

(14) A. Reiche, H. Gross, and E. Hoft, *Chem. Ber.*, **93**, 88 (1960).

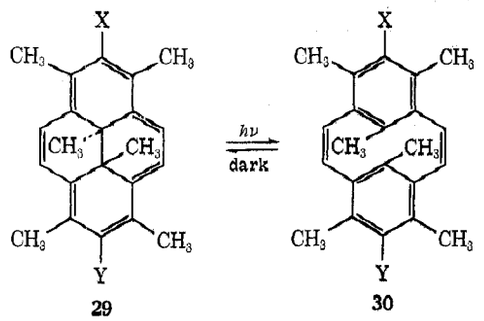
(15) Likewise, 2-ethoxydimethyldihydropyrene is an unstable oil; *cf.* ref 2.

(16) (a) R. M. Evans, *Quart. Rev. Chem. Soc.*, **13**, 61 (1959); (b) H. R. Blattman and W. Schmidt, *Tetrahedron*, **26**, 5885 (1970).



The 2-formyl compound could also be converted to the oxime **27** which, on dehydration, formed the 2-cyano derivative **28**. Both the oximino and cyano groups are conjugated with the π system, as judged by infrared and nmr spectra. The cyano group of course has linear geometry and should experience little steric hindrance by the adjacent methyl groups.

The unique phototautomerization **29** $\rightleftarrows$ **30** which has



been reported for 15,16-dihydropyrenes[2,3,9] occurs as well with the hexamethyl derivatives which have been studied. The rate of the dark reaction was found to be greatly influenced by the nature of substituents X and Y. A detailed study of this phenomenon has been reported.[16b]

For an estimation of its resonance energy, a sample of hexamethyl-15,16-dihydropyrene was submitted to Professor J. L. Margrave for combustion studies. The stabilization energy was evaluated as 68.6 kcal mol^{-1}; these studies will be reported elsewhere.

Experimental Section

General.—All melting points were observed in open-end soft glass capillaries with a Thomas–Hoover apparatus and are uncorrected. Column chromatographies were run on silica gel, mesh size 200 × 235, supplied by the Davidson Division, Grace Chemical Corp.; thin-layer chromatograms were developed on silica gel GF, containing phosphor, supplied by Brinkmann Instruments, and were observed visually and by short and long wavelength ultraviolet light. Organic extracts were washed with a concentrated sodium chloride solution, dried over anhydrous magnesium sulfate, and concentrated under water aspirator vacuum in a rotary evaporator. Nuclear magnetic resonance spectra were recorded with a Varian A-60, in deuteriochloroform unless specified, and infrared spectra were taken with a Perkin-Elmer 21 instrument. All ultraviolet–visible absorption spectra were determined with a Cary 14 recording spectrophotometer; solutions of hexamethyldihydropyrane derivatives were prepared in a darkened room and allowed to stand 48 hr in the dark before spectra were recorded.

Methoxymesitylene (7).—To 272.4 g (2.0 mol) of 2,4,6-trimethylphenol was added a solution of 80 g (2.0 mol) of sodium hydroxide in 800 ml of water. After being stirred 45 min at room temperature, the solution was cooled to 15–20° in an ice bath, and 188 ml (252 g, 2.0 mol) of dimethyl sulfate was added over 1 hr. The resulting suspension was heated at 85–95° for *ca.* 2 hr, after which time a second mole of sodium hydroxide was added and the suspension was heated at 95° for 12 hr. An additional 0.5 mol of sodium hydroxide and 0.5 mol of dimethyl sulfate were added, and heating at 95° was continued for 3 hr. After cooling, the two-phase suspension was extracted with ether. The combined ether extracts were shaken with 25% sodium hydroxide solution. The organic layer yielded 273.5 g of a clear pale-gold liquid. Distillation at 32° (0.3 mm) gave 248.2 g (82%) of product, n^{20}D 1.5041 (lit.[17] 1.5040).

4,6-Bis(chloromethyl)methoxymesitylene (8).—To 198 g (1.32 mol) of 2-methoxymesitylene were added 1400 ml of concentrated hydrochloric acid and 78.4 g (0.87 mol) of *s*-trioxane. Hydrogen chloride was then passed through the stirred suspension, which was warmed at 80–90° for 12–15 hr. The reaction slurry was cooled and the crude product was collected by filtration. The solid obtained was washed with water several times, dissolved in methylene chloride, and washed with sodium bicarbonate solution.

The organic layer was dried and concentrated; the residue, after slurrying with heptane, yielded the product as white needles, 234.2 g (72%), mp 138–139°. The analytical sample was prepared by recrystallization from heptane: nmr singlets at 2.39 (6, methyls), 2.45 (3, methyl), 3.68 (3, *o*-methyl), and 4.67 (4, $-CH_2Cl$).

Anal. Calcd for $C_{12}H_{16}OCl_2$: C, 58.31; H, 6.53. Found: C, 58.33; H, 6.39.

Hexamethyl-5,13-dimethoxy[2.2]metacyclophane (9).—A three-necked flask equipped with a Vibromixer[18] and condenser was flame-dried, while a stream of prepurified nitrogen purged the system, and the flask was allowed to cool under a positive pressure of nitrogen, controlled by a mercury bubbler. To the flask was added 200 ml of dry toluene, 20 g of freshly cut sodium pieces, and *ca.* ten drops of oleic acid. A fine sodium sand was prepared according to the procedure of Whaley.[19] The oil bath temperature was raised to 130–140° and, when all the sodium had melted (the sodium pieces, on melting, usually float to the surface of the toluene, encapsulated in sodium oleate), agitation provided by the Vibromixer was carried out for 15 min. At the end of this time agitation was stopped, and the sodium sand was allowed to cool *without stirring*.

To this mixture was added a solution of 750 mg of tetraphenylethylene in 300 ml of tetrahydrofuran (distilled from lithium aluminum hydride and stored over sodium); a deep red color forms immediately.

A 1-l. Hershberg dropping funnel[20] was attached to the flask, under the same nitrogen pressure, and a solution of 30 g of 4,6-bis(chloromethyl)methoxymesitylene in 700 ml of tetrahydrofuran was added at a rate of 20–25 drops/min. Throughout the addition, slow agitation was provided by the Vibromixer.

Addition of the first charge was complete in 15 hr. A second 30-g charge was added over 15 hr. A few drops of ethanol were then added to destroy the red color and, after standing for several minutes to allow the unreacted sodium to settle, the suspension was decanted from most of the unreacted sodium. The reaction flask and Supercel pad were washed with additional tetrahydrofuran, and the clear colorless filtrate was concentrated, yielding a crystalline residue.

This residue was dissolved in 600 ml of methylene chloride–ether (1:1), filtered, and washed with 6 *N* hydrochloric acid, and the organic layer was concentrated to a volume of 300 ml and

(17) K. von Auwers, *Ann.*, **415**, 156 (1914).
(18) Available from Chemapec, Inc., One Newark Street, Hoboken, N. J.
(19) T. P. Whaley, *Inorg. Syn.*, **5**, 6 (1956).
(20) For a description see K. B. Wiberg, "Laboratory Techniques in Organic Chemistry," McGraw-Hill, New York, N. Y., 1960, pp 206–208.

applied to a 1.5 in. × 24 in. column of dry-packed Florisil (60–200 mesh). Of six 300-ml fractions collected, fractions 2, 3, and 4 contained 17.28 g (35%) of white crystals, mp 220–230°, which contained 86% metacyclophane (*via* nmr). Two recrystallizations from ethanol–heptane yielded clear colorless prisms: mp 234–235°; nmr τ 3.58 (s, 2 $-OCH_3$), 7.5 (A_2B_2 m, 2 $-CH_2PH_2-$), 7.69 (s, 4 CH_3), and 9.50 (s, 8,16-methyls).

Anal. Calcd for $C_{24}H_{32}O_2$: C, 81.77; H, 9.15. Found: C, 81.71; H, 8.89.

The crude product was suitable for conversion to the hexamethyl bis(dienone). Two runs using the 4,6-bis(iodomethyl) compound gave yields of only 17%.

Continued elution of the column produced the corresponding [2.2.2.2]metacyclophane (*ca.* 5%), mp 275–280°, the nmr spectrum of which showed signals at τ 6.32 (s, 4 $-OCH_3$), 7.34 (s, 8 $-CH_2-$), 7.70 (s, 8 external $-CH_3$), and 8.75 (s, 4 internal $-CH_3$).

Hexamethylbis(dienone) 10.—A chromic acid solution was prepared by treating 8.0 g of chromium trioxide with 3–4 ml of water, followed by 6.4 ml of sulfuric acid and dilution with water to a total volume of 30 ml.

To a stirred suspension of 6.7 g (0.019 mol) of **9**, mp 230–235°, in 500 ml of acetone were added dropwise 15 ml of this solution over 15–20 min. Near completion of the addition, a green pasty precipitate formed which became more solid after 1.5 hr of stirring.

This was extracted with water–methylene chloride (1.5–1.0). The organic extract yielded a light yellow residue which was washed with acetone, leaving a very pale cream-colored crystalline solid, wt 5.77 g (94%), mp 341–343°. Recrystallization from chloroform raised the melting point to 345–347°; λ_{max}^{MeOH} 270 mμ (ϵ 31,000); ir ν_{max}^{KBr} 1660 cm^{-1} (s) and 1620 cm^{-1} (s); nmr τ 7.15 (m, 8 H), 7.92 (s, 4 CH_3), and 8.87 (s, internal CH_3's).

Anal. Calcd for $C_{22}H_{26}O_2$: C, 81.95; H, 8.13. Found: C, 81.71; H, 8.07.

Hexamethyldihydropyrene-2,7-quinone (11).—Hexamethylbis(dienone) (11.6 g, 0.036 ml) was added to a solution of potassium hydroxide (5 g) and dissolved in 1500 ml of warm absolute ethanol, and the slurry was maintained at 55° for 17 hr, while a slow stream of oxygen was passed over the reaction mixture. The dark red solution was cooled to room temperature and acidified slowly with concentrated hydrochloric acid. The red-orange mixture was filtered and the filtrate was concentrated. The residue was dissolved in 300–500 ml of chloroform, washed with brine, dried, concentrated to a volume of *ca.* 300 ml, and chromatograped over 800 g of silica gel. A dark maroon band was collected and yielded a bright red solid. Drying at 40° for 12 hr gave 9.10 g (79.5%) of a bright orange solid, mp 282–284°. The analytical sample was prepared by sublimation at 180–185° (0.01 mm): mp 284–285°; λ_{max}^{MeOH} 225 mμ (ϵ 23,000), 286 (54,000), 295 (58,450), and 348 (15,000); ir ν_{max}^{KBr} 1640 cm^{-1} (sh, s) and 1625 cm^{-1} (s); nmr τ 3.45 (s, 4 H), 7.98 (s, 2 internal methyls), and 8.05 (s, 4 external methyls).

Anal. Calcd for $C_{22}H_{22}O_2$: C, 82.98; H, 6.96. Found: C, 82.91; H, 6.84.

In many runs a sediment remained in the ethanol after oxidation which was the [2.2.2.2]metacyclophane impurity in the bis-dienone; this was the best point at which to collect this side product.

1,3,6,8,15,16-Hexamethyl-*trans*-15,16-dihydropyrene (2). A. Reduction of 2,7-Quinone.—A reducing solution was prepared by heating at reflux 40 g of aluminum chloride and 12 g of lithium aluminum hydride in 500 ml of dry ether.

After cooling, the clear supernatant solution was carefully decanted into a 3-l. reaction flask. Six grams of hexamethyldihydropyrene-2,7-quinone was dissolved in 100 ml of dry tetrahydrofuran and diluted to *ca.* 500 ml with ether. This red solution was added dropwise over 2 hr to the reducing solution at room temperature, which gained a deep green color; the suspension was then heated at reflux temperature for 1 hr.

After cooling, 30–50 ml of ethyl acetate was added, followed by water, with vigorous stirring until the reaction mixture formed two clear phases. The organic layer, after work-up, gave a dark green residue which was dried for 12–15 hr at 40° in a vacuum oven. The nmr spectrum of this material indicated that it was a 3:2 mixture of **2** and **12**; those resonances assigned to **12** are τ 3.62 (s, 4 H, 4, 5, 9, and 10 protons), 7.16 (broad s, 2- and 7-methylenes), 8.12 (s, external methyls), and 9.14 (s, internal methyls). This mixture was subjected directly to the following dehydrogenation.

B. Dehydrogenation of Hexamethylbis(triene) (12).—The dark green residue from above was dissolved in 250 ml of dry toluene and heated to reflux temperature with 4 g of 10% palladium on charcoal for 15–18 hr. The progress of the reaction was followed by thin-layer chromatography (hexane); no dehydrogenations proceeded to 100% completion. Filtration and concentration of the dark mixture yielded 4.55 g of solid, mp 180–185°, which was boiled in methanol for several minutes and collected, wt −4.06 g (75% from quinone), mp 182–185°. The analytical sample was prepared from heptane: dark blue-green prisms; mp 184–186°; $\lambda_{max}^{CH_2Cl_2}$ 274 mμ (ϵ 10,650), 358 (97,850), 390 (37,400), 417 (6250), 446 (5200), 474 (4450), 548 (70), 602 (150), 610 (150), 637 (100), 656 (150); nmr τ 1.44 (s, 4 H), 2.20 (s, 2 H), 6.84 (s, external methyls), and 14.04 (s, internal methyls).

Anal. Calcd for $C_{22}H_{24}$: C, 91.61; H, 8.39. Found: C, 91.50; H, 8.22.

Mass spectral analysis of **2** shows, in addition to ions at *m/e* 318 ($M^+ + 2CH_3$, 0.5% base peak), 303 ($M^+ + CH_3$, 5%), 288 ($M^+ + CH_3$, 5%), 288 (M^+, 3%), 273 ($M^+ - CH_3$, 25%), essentially one intense fragment at 258 ($M^+ - 2CH_3$), corresponding to the stable tetramethylpyrene cation.[21]

2,7-Diacetoxyhexamethyldihydropyrene (13).—To a mixture of 500 mg of **11** in 50 ml of acetic anhydride and six drops of triethylamine at room temperature was added portionwise over 5 min 1.0 g of zinc dust; a color change from red to green became apparent in about 2 min. The mixture was stirred for 4 hr and quenched by pouring the dark green mixture into ice and water. The aqueous suspension, after 2 hr, was then extracted with methylene chloride–ether. The organic layer, after work-up, gave a dark green residue which smelled strongly of acetic acid. The residue, after slurrying in methanol, gave 500 mg (78%), mp 238–239°, of crude product which was recrystallized from methylene chloride–heptane, and sublimed at 180° (0.01 mm) producing a dark green solid: mp 239–240°; $\lambda_{max}^{CH_2Cl_2}$ 357 mμ (ϵ 109,000), 385 (39,600), 413 (7300), 451 (6200), 468 (6200), 541 (100), 608 (150), 642 (250), and 647 (250); ir ν_{max}^{KBr} 1755 cm^{-1} (s), 1370 (s), 1215 (vs), 1175 (vs), and 1080 (vs); nmr τ 1.34 (s, 4 H), 7.00 (s, external methyls), 7.46 (s, acetoxy methyls), and 13.88 (s, internal methyls).

Anal. Calcd for $C_{26}H_{28}O_4$: C, 77.20; H, 6.98. Found: C, 77.48; H, 7.08.

2-Acetylhexamethyldihydropyrene (14, X = Ac).—To a solution of 500 mg of hexamethyldihydropyrene in 25 ml of methylene chloride was added dropwise over 45 min a solution of 0.17 ml of acetic anhydride and 0.10 ml of stannic chloride in 25 ml of methylene chloride. After several hours thin layer chromatography (heptane–ethyl acetate, 90:10) indicated a mixture of isomeric acetylhexamethyldihydropyrenes and an appreciable amount of starting material. After 18 hr the reaction was poured into ice water and this mixture was stirred for 2 hr and extracted with methylene chloride–ether. The residue from the organic extract was chromatographed on silica gel with methylene chloride. A green band was eluted rapidly, which was identified as starting material, 243 mg. Slowly a second green band was eluted with methylene chloride, 145 mg (49%), mp 202–203°, which was 2-acetylhexamethyldihydropyrene [sublimation at 120–130° (0.01 mm) raised the melting point to 205–206°]: $\lambda_{max}^{CH_2Cl_2}$ 361 mμ (ϵ 106,000), 392 (39,900), 457 (5600), 478 (5800), 549 (100), 603 (200), and 659 (150); ir ν_{max}^{KBr} 1710 cm^{-1} (s); nmr τ 1.36 (s, 4 H), 2.20 (s, 1 H), 6.85 and 6.95 (2 s, external methyls), 7.20 (s, acetyl methyl), and 13.84 (s, internal methyls).

Anal. Calcd for $C_{24}H_{26}O$: C, 87.23; H, 7.93. Found: 87.02; H, 7.67.

2,7-Diacetylhexamethyldihydropyrene (17).—To a solution of hexamethyldihydropyrene (490 mg) in 25 ml of methylene chloride was added all at once a solution of 0.2 ml of acetic anhydride and 0.1 ml of stannic chloride in 25 ml of methylene chloride. Thin-layer chromatography (methylene chloride–heptane, 75:25) indicated the presence of both mono- and diacetyl products after 2 min. After 1.5 hr, 15 ml of 2 *N* hydrochloric acid was added. The organic layer was dried, concentrated to a volume of 25 ml, and applied to a silica gel column. A small green band of hexamethyldihydropyrene (25 mg) was eluted rapidly. This was followed by 2-acetylhexamethyldihydropyrene (55 mg). Continued elution with methylene chloride and methylene chloride–3% ether produced 46 mg of an oil which was identical to a

(21) Mass spectra were determined by Dr. Paul C. Nicolson of these laboratories on a C.E.C. model 21-103C instrument using a heated inlet operating at 220°.

similar fraction obtained in the monoacetylation experiment, and is probably the 4-acetyl isomer.

A dark olive-gold fraction was then eluted which contained 240 mg (39%) of crude 2,7-diacetylhexamethyldihydropyrene. This material, after recrystallization from methylene chloride–methanol, yielded 103 mg of long green prisms: mp 226–227°; $\lambda_{max}^{CH_2Cl_2}$ 363 mμ (ε 101,750), 395 (32,900), 482 (6600), 552 (100), 608 (200), and 665 (200); ir ν_{max}^{KBr} 1705 cm^{-1} (s) and 1205 cm^{-1} (s); nmr singlet resonances at τ 1.32 (4 H), 6.95 (external methyls), 7.22 (acetyl methyls), and 13.78 (internal methyls).

Anal. Calcd for $C_{26}H_{28}O_2$: C, 83.83; H, 7.58. Found: 83.74; H, 7.58.

Nitration of Hexamethyldihydropyrene.—Hexamethyldihydropyrene (1.40 g, 4.85 mol) was slurried in 100 ml of acetic anhydride, and 590 mg (4.85 mol) of powdered cupric nitrate (trihydrate) was added over 5 min. After 15 min the green color had changed to a dark olive-gold. Thin layer chromatography (methylene chloride–heptane, 50:50) indicated the presence of two new components. After 1.5 hr the dark solution was poured into ice water and stirred until the acetic anhydride had reacted. The resulting mixture was extracted with methylene chloride–ether.

The crude residue from the organic extract, after reconcentration twice from toluene to remove acetic acid, was dissolved in 100 ml of 30% methylene chloride in heptane and chromatographed on 400 g of silica gel. A green band of unreacted starting material (139 mg) was eluted rapidly with 5% methylene chloride–heptane. Two large dark bands then moved slowly down the column; 20% methylene chloride–heptane eluted the 2-nitro compound cleanly, followed by clean elution of the 4-nitro isomer with 40% methylene chloride–heptane.

The first fraction yielded 706 mg (49%), mp 223–224°, of 2-nitrohexamethyldihydropyrene (**14**, X = NO_2), and the second fraction yielded 375 mg (26%), mp 203–205°, of 4-nitrohexamethyldihydropyrene (**15**, X = NO_2). Both fractions were homogenous on thin-layer chromatography.

2-Nitrohexamethyldihydropyrene could be recrystallized from methylene chloride–methanol, which yielded purple-black needles, mp 224–226°. The analytical sample was sublimed at 130–140° (0.01 mm): $\lambda_{max}^{CH_2Cl_2}$ 359 mμ (ε 81,850), 388 (30,600), 480 (5100), 593 (500), and 658 (350); ir ν_{max}^{KBr} 1521 cm^{-1} (vs), 1460 (s), 1333 (s); nmr singlet resonances at τ 1.24 (4 H), 2.06 (1 H), 6.83 and 6.92 (external methyls), and 13.88 [2, $(\nu_1 - \nu_2)$ = 3 Hz, internal methyls].

Anal. Calcd for $C_{22}H_{23}NO_2$: C, 79.25; H, 6.95; N, 4.20. Found: C, 79.19; H, 6.99; N, 4.40.

4-Nitrohexamethyldihydropyrene was recrystallized from methylene chloride–methanol, yielding purple-black needles, mp 207–209°. The analytical sample was sublimed at 130° (0.01 mm): $\lambda_{max}^{CH_2Cl_2}$ 354 mμ (ε 14,200), 392 (9700), 6.08 (500), and 671 (600); ir ν_{max}^{KBr} 1524 cm^{-1} (vs) and 1328 cm^{-1} (s); nmr singlets at τ 1.18 (C_5 proton), 1.44 (2 H, 9 and 10 protons), 2.18 [2 s, $(\nu_1 - \nu_2)$ = 0.5 Hz, 2 H], 6.90 (1-, 6-, 8-methyls), 7.18 (3-methyl), and 13.68 [2 s, $(\nu_1 - \nu_2)$ = 3 Hz, internal methyls].

Anal. Calcd for $C_{22}H_{23}NO_2$: C, 79.25; H, 6.95; N, 4.20. Found: C, 79.42; H, 7.02; N, 4.39.

2-Formylhexamethyldihydropyrene (14, X = CHO).—To a solution of hexamethyldihydropyrene (956 mg) in 50 ml of dry methylene chloride was added at room temperature 0.5 ml of stannic chloride and 1.0 ml of dichloromethylbutyl ether (3 mol equiv). The dark green solution was stirred at room temperature for 17 hr, during which time starting material was completely consumed as indicated by thin-layer chromatography (heptane–ethyl acetate, 90:10), and poured into water. The aqueous burgundy-red suspension was stirred for 15 min and extracted with methylene chloride–ether. The organic residue in methylene chloride was applied to a silica gel column. A dark maroon band was eluted with 3% ethyl acetate–methylene chloride. Toward the end of the elution the color changed from burgundy to red-brown, and a second fraction was taken. The main fraction yielded 850 mg (81%) of the 2-formyl isomer, mp 213–215°, and the red-brown fraction yielded 95 mg (9%) of the 4-formyl isomer (**15**, X = CHO), mp 203–205°. Thin layer chromatography indicated both fractions to be homogenous.

The 2-formyl compound was recrystallized from methanol in black-red needles: mp 214–216°; $\lambda_{max}^{CH_2Cl_2}$ 243 mμ (ε 12,300), 369 (77,100), 412 (21,200), 518 (8750); 631 (600), and 698 (1300); ν_{max}^{KBr} 1675 cm^{-1}; nmr τ −1.36 (s, –CHO), 1.33 [center of AB quartet (*J* = 8 Hz), 4 H], 2.18 (broad s, 1 H), 6.65 and 6.90 (2 s, external methyls), and 13.68 [2 s, $(\nu_1 - \nu_2)$ = 3 Hz, internal methyls].

Anal. Calcd for $C_{23}H_{24}O$: C, 87.30; H, 7.65. Found: C, 87.22; H, 7.74.

The 4-formyl isomer was also recrystallized from methanol, giving essentially black prisms: mp 204–205°; $\lambda_{max}^{CH_2Cl_2}$ 280 mμ (ε 8000), 395 (42,500), 447 (5400), 503 (6000), 616 (700), and 680 (1700); ir ν_{max}^{KBr} 1681 cm^{-1} (sh, s) and 1656 cm^{-1} (vs); nmr τ 1.38 (s, –CHO), 0.82 (s, C_5 proton), 153 [center of AB quartet (*J* = 8 Hz, 2 H], 2.12 (s, 1 H), 2.20 (s, 1 H), 6.70 and 6.90 (3, 4 external methyls), 13.58 and 13.66 (2 s, internal methyls).

Anal. Found: C, 87.14; H, 7.43.

2-Acetamidohexamethyldihydropyrene (19).—To a suspension of 20 ml of acetic anhydride, 20 ml of acetic acid, 200 mg of 2-nitrohexamethyldihydropyrene, and 200 mg of sodium acetate was added portionwise over 10 min 500 mg of zinc dust. The mixture was stirred at 20° for 15 hr. The color changed slowly from a dark brown-gold to a dark green over 5 hr. The mixture was poured into ice water and extracted with methylene chloride–ether. The organic layer, after concentration, yielded 188 mg (91%) of 2-acetamidohexamethyldihydropyrene: mp 214–216° (recrystallization from methylene chloride–heptane raised the melting point to 215–217°); ir ν_{max}^{KBr} 3250 cm^{-1} (w, 1660 cm^{-1} (vs), 1525 cm^{-1} (m); nmr (DMSO-d_6) τ 0.00 (broad s, NH), 1.40 (s, 4 H), 2.14 (s, 1 H), 6.94 and 7.02 (equiv s, external methyls), 7.72 (s, –$COCH_3$), and 14.06 (s, internal methyls).

Anal. Calcd for $C_{24}H_{27}NO$: C, 83.44; H, 7.88; N, 4.05. Found: C, 83.56; H, 7.93; N, 4.02.

2-Acetamido-7-formylhexamethyldihydropyrene (20).—To a stirred solution of 400 mg of **19** in 50 ml of methylene chloride was added 0.2 ml of stannic chloride followed by 0.4 ml of dichloromethylbutyl ether (twofold excess). After 3 hr the reaction solution was poured into water. The deep burgundy-red suspension was extracted with methylene chloride–ether and the organic extract was concentrated and reconcentrated from toluene to remove traces of acetic acid. Chromatography of the dark maroon residue (426 mg) on silica gel using 50% ethyl acetate–heptane as eluting solvent yielded 182 mg (42%) of 2-acetamido-7-formylhexamethyldihydropyrene, together with a lesser component, which is probably the 2-acetamido-4-formyl compound. Recrystallization of this material from methylene chloride–heptane yielded a dark maroon solid: mp 216–218°; ir ν_{max}^{KBr} 3300 cm^{-1} (m), 1675 cm^{-1} (vs), and 1575 cm^{-1} (m); nmr τ −1.32 (s, –CHO), 1.35 [center of AB quartet, (*J* = 8 Hz), 4 H], 2.30 (broad s, NH), 6.70 (s, 2 CH_3) 7.00 (broad s, 2 CH_3), 7.60 (broad s, –$COCH_3$), and 13.58 [2 s, $(\nu_1 - \nu_2)$ = 5 Hz, internal methyls].

Anal. Calcd for $C_{25}H_{27}NO_2$: C, 80.39; H, 7.29; N, 3.75. Found: C, 80.31; H, 7.25; N, 3.79.

4-Acetamidohexamethyldihydropyrene (23).—To a mixture of 200 mg of 4-nitrohexamethyldihydropyrene in 20 ml of acetic acid and 20 ml of acetic anhydride was added 200 mg of sodium acetate, followed by the portionwise addition of 500 mg of zinc dust over 10 min at 20°. The dark olive-gold mixture changed rapidly over 0.5 hr in color to a dark green. After 2.5 hr, thin layer chromatography (ethyl acetate–heptane, 75:25) indicated complete consumption of starting material. The reaction mixture was poured into ice water and resulting suspension was extracted with chloroform–ether. The organic layer yielded 197 mg (95%) of a dark green solid. Recrystallization from chloroform–heptane gave dark green microprisms: mp 229–231°; ir ν_{max}^{KBr} 3550 cm^{-1} (m), 1680 cm^{-1} (sh s), 1660 cm^{-1} (v s), and 1555 cm^{-1} (s); nmr τ 1.40 (broad s, 3 H), 2.00 (broad s, NH), 2.20 (s, 2 H), 6.80 (2 nonequiv overlapping s, external methyls), 7.80 (s, –$COCH_3$), and 13.78 [2 s, $(\nu_1 - \nu_2)$ = 3 Hz, internal methyls].

Anal. Calcd for $C_{24}H_{27}NO$: C, 83.44; H, 7.88; N, 4.05. Found: C, 83.64; H, 7.58; N, 4.01.

2-Hydroxymethylhexamethyldihydropyrene (25, R = CH_2OH).—To 75 ml of absolute ether in a 200-ml three-necked flask was added carefully 400 mg of lithium aluminum hydride, and to this slurry was added, over 45 min, a solution of 300 mg of 2-formylhexamethyldihydropyrene in 50 ml of tetrahydrofuran. Immediately a dark green color formed. After addition was complete the reaction was stopped by addition of 30 ml of ethyl acetate, followed by 30 ml of water. The organic layer after work-up yielded a dark green solid, wt 295 mg (98%), mp 210–212°; ir spectra showed no carbonyl band. The analytical sample was recrystallized from methanol: mp 212–214°; nmr τ 1.38 [center of AB quartet, (*J* = 9 Hz), 4 H], 2.30 (s, 1 H), 4.58 (s, –CH_2–),

6.72 and 6.85 (equiv s, external methyls), and 13.83 [s, ($\nu_1 - \nu_2$) = 2 Hz, internal methyls].

Anal. Calcd for $C_{28}H_{26}O$: C, 86.74; H, 8.23. Found: C, 86.75; H, 8.23.

When the product was treated in refluxing chloroform with manganese dioxide, a near quantitative recovery of 2-formylhexamethyldihydropyrene resulted.

Heptamethyldihydropyrene (26, R = CH_3).—Into a 300-ml three-necked flask was decanted 50 ml of a hydride solution described in the reduction of 11 to 2. To this was added dropwise over 0.5 hr a deep red solution of 400 mg of 2-formyl-hexamethyldihydropyrene in 20 ml of tetrahydrofuran and 50 ml of ether. A dark green solution immediately resulted. This slurry was heated at reflux temperature for 1 hr and, after cooling, the excess reductant was destroyed by addition of 30 ml of ethyl acetate, followed by 30 ml of water. The organic layer yielded 387 mg (99%) of a dark green solid. Recrystallization from methylene chloride–heptane gave the analytical sample: mp 213–214°; ir spectra (Nujol) showed the absence of carbonyl or hydroxy bands; nmr τ 1.40 (s, 4 H), 2.27 (s, 1 H), 6.86 (s, 1-, 3-, 6-, and 8-methyls), 7.08 (s, 2-methyl), 13.95 and 13.98 (s, internal methyls).

Anal. Calcd for $C_{28}H_{26}$: C, 91.33; H, 8.67. Found: C, 91.32; H, 8.65.

2-Hexamethyldihydropyrene Aldoxime (27).—To a slurry of 514 mg of the 2-formyl derivative **24** in 50 ml of ethanol were added 5 ml of an aqueous hydroxylamine hydrochloride solution which had been neutralized to pH 7 with sodium carbonate. This was warmed on a steam bath for 15 min, after which time thin layer chromatography showed complete conversion of starting material. Careful addition of water to the dark solution while hot resulted in a crystallization of the oxime on cooling, wt 508 mg (94%), mp 205–207°. Recrystallization from ethanol yielded olive-brown platelets: mp 210–211°; $\lambda_{max}^{CH_2Cl_2}$ 245 mμ (ϵ 12,200), 363 (106,300), 396 (32,300), 486 (8000), 610 (200), and 666 (350); ir $\nu_{max}^{CH_2Cl_2}$ 3600 cm^{-1} (s), 3300 (m), 1625 (w), and 1450 (s); nmr (DMSO-d_6) τ −1.42 (s, C=NOH), 0.96 (s, -CH=N-), 1.36 [AB quartet (J = 8 Hz), 4 H], 2.16 (s, 1 H), 6.90 (two equiv s, external methyls), and 13.94 (s, internal methyls).

Anal. Calcd for $C_{28}H_{26}NO$: C, 83.34; H, 7.60; N, 4.23. Found: C, 83.14; H, 7.49; N, 4.09.

2-Cyanohexamethyldihydropyrene (28).—Acetic anhydride (20 ml) and 244 mg of **27** were mixed and heated at reflux temperature for 15 min. After cooling, the dark solution was poured into water. When all solvent had reacted, the mixture was extracted with a mixture of methylene chloride and ether. The residue from the organic extract was twice recovered from toluene to remove traces of acetic acid, and was chromatographed on silica gel with methylene chloride–heptane (50:50). A dark bronze band was eluted to give 99 mg (43%) of **28**, mp 218–219°. Recrystallization from methanol produced fine, olive-brown needles: mp 215–216°; $\lambda_{max}^{CH_2Cl_2}$ 365 mμ (ϵ 91,000), 402 (39,800), 505 (9700), 611 (800), and 678 (1800); ir $\nu_{max}^{CHCl_3}$ 2210 cm^{-1} (vs) and 1445 cm^{-1} (s); nmr τ 1.33 [AB quartet, (J = 8 Hz), 4 H], 2.08 (s, 1 H), 6.60 and 6.84 (equiv s, external methyls), and 13.87 (s, internal methyls).

Anal. Calcd for $C_{23}H_{23}N$: C, 88.13; H, 7.40; N, 4.47. Found: C, 87.93; H, 7.39; N, 4.51.

Registry No.—**2**, 20349-16-0; **7**, 4028-66-4; **8**, 16927-60-9; **9**, 20518-37-0; **10**, 21654-31-9; **11**, 21654-32-0; **13**, 35051-08-2; **14** (X = Ac), 32347-25-4; **14** (X = NO_2), 32347-21-0; **14** (X = CHO), 32347-27-6; **15** (X = NO_2), 33872-82-1; **15** (X = CHO), 32347-29-8; **17**, 32347-24-3; **19**, 35051-15-1; **20**, 35051-16-2; **23**, 35051-17-3; **25**, 35051-18-4; **26**, 32500-00-8; **27**, 32347-26-5; **28**, 32347-28-7.

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The Retentive Nucleophilic Displacements of α-Substituted Alkylferrocenes[1]

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Ferrocenylethane derivatives with suitable leaving groups [chloro, acetate (**9**), trimethylammonium (**2**)] in the α position generally undergo nucleophilic substitutions with complete retention of configuration and are useful for the preparation of a variety of chiral ferrocene derivatives. Stereochemical and kinetic evidence indicates an SN1 mechanism *via* a configurationally stable α-ferrocenylethyl carbonium ion intermediate. Departure of the leaving group and entry of the substituting nucleophile involve analogous conformations of the α-ferrocenylalkyl system. Winstein–Grunwald *m*Y analysis of ammonium compound **2** indicates only a very slight solvent effect for solvolysis in this stable carbonium ion system.

Chiral ferrocene derivatives[3] with the general formula **5** and analogous compounds may serve as asymmetrically inducing amine components[4] in stereoselective peptide synthesis by four-component condensations,[5] *i.e.*, **3** → **4**, because primary amines related to **3** are not only effective steric templates without excessive steric bulk, but their condensation products (**4**) may also be readily cleaved, **4** → **5** + **6**, under mild conditions.[5] The use of **3** as an asymmetrically inducing amine component in four-component condensations offers further advantages. Model reactions[5-7] indicate that the cleavage products can be used to resynthesize the amines. Both antipodes of optically active **1** are easy to obtain and can be effectively converted into compounds of type **1** with a sub-

(1) Stereoselective Syntheses. VIII.

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