dropwise at 5–10° with stirring and the stirring was then continued for 15 hours. Approximately 200 ml. of water was then added and the benzene layer was separated, dried over sodium sulfate and concentrated. The residue was distilled at reduced pressure and the fraction boiling at 172–178° (0.04 mm.) was collected. This was crystallized from 95% ethanol; yield 33.5 g. (54%), m.p. 66.5–67.5° (lit.[2] 68.4–69.0°).

Anal. Calcd. for $C_{11}H_{12}O_5$: C, 58.92; H, 5.39. Found: C, 59.06; H, 5.54.

3-(*o*-Methoxyphenoxy)-2-hydroxypropyl N,N-Dimethylcarbamate (IX).—A solution of 98 g. (1.0 mole) of phosgene in 200 ml. of cold benzene was added dropwise with stirring at 30° to a suspension of 198 g. (1.0 mole) of 3-(*o*-methoxyphenoxy)-1,2-propanediol (II) and stirring was continued for 3 hours after which all of the propanediol had dissolved. The solution was then cooled to 10° and 79 g. (1.0 mole) of pyridine was added portionwise so that the temperature did not rise above 30° and the mixture was held at this temperature with stirring for an additional 30 minutes. The benzene solution was then washed with two 500-cc. portions of ice-water and added to a cold, saturated aqueous solution of dimethylamine with stirring and cooling. These reaction conditions were continued for 6 hours; the benzene layer was separated and concentrated; and the residual oil was fractionated; yield 222 g. (82.5%), b.p. 172–178° (0.1 mm.).

Anal. Calcd. for $C_{13}H_{19}NO_5$: N, 5.21. Found: N, 5.10.

1-[2-Hydroxy-3-(*o*-methoxyphenoxy)-propyl]-urea (VIII).—A solution of 10.3 g. (0.127 mole) of potassium cyanate in 25 ml. of water was added to a solution of 25 g. (0.127 mole) of 1-amino-3-(*o*-methoxyphenoxy)-2-propanol (V) and 12 ml. of concentrated hydrochloric acid in 100 ml. of water. The resulting solution was warmed to 50° during a 10-minute period and then cooled in an ice-bath for 1 hour, which caused precipitation of the product; yield 28 g. (92%), m.p. 124–126°. After several crystallizations from absolute ethanol the m.p. was 129.5–130.5°.

Anal. Calcd. for $C_{11}H_{16}N_2O_4$: N, 11.66. Found: N, 11.64.

The N-substituted oxazolidinones were prepared by the condensation of the amino alcohol with diethyl carbonate or phosgene. The following are typical examples of these procedures:

5-(*p*-Bromophenoxymethyl)-3-ethyl-2-oxazolidinone.—To a solution of 45.0 g. (0.16 mole) of 3-(*p*-bromophenoxy)-1-ethylamino-2-propanol and 19.4 g. (0.16 mole) of diethyl carbonate in 200 ml. of isoöctane was added 0.1 g. of sodium metal; and the mixture was stirred and heated at 95–100° for 30 minutes while the ethanol–isoöctane azeotrope was allowed to distil out. The reaction was practically complete in 15 minutes and the insoluble oxazolidinone precipitated from solution; yield 48.4 g. (98.2%), m.p. 122.5°. Recrystallization from isoöctane did not elevate the melting point.

5-(*o*-Methoxyphenoxymethyl)-2-oxazolidinone-2-C^{14}.—A solution of 0.99 g. (10 mmoles) of phosgene containing 3 mc. of phosgene-C^{14} in 9 ml. of chloroform was added to a cooled solution of 1.97 g. (10 mmoles) of 1-amino-3-(*o*-methoxyphenoxy)-2-propanol (V) at 5° with stirring over a 30-minute period. The mixture was then allowed to stir at 30° for 1 hour, cooled to 5° and 1.58 g. (20 mmoles) of pyridine in 10 ml. of chloroform was added dropwise over a 15-minute period. The mixture was then stirred for 3 hours at 30°, extracted with two 20-ml. portions of cold water, dried over sodium sulfate, concentrated to *ca.* 15 ml. and diluted with *ca.* 30 ml. of petroleum ether (b.p. 30–60°) which caused crystallization of the product, yield 0.435 g., 1.25 mc. of C^{14} (41.6%), m.p. 141.5–142°.

RICHMOND 20, VA.

[CONTRIBUTION FROM THE DEPARTMENT OF CHEMISTRY, UNIVERSITY OF CALIFORNIA, BERKELEY]

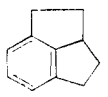
2,2a,3,3a,4,5-Hexahydro-1H-cyclopent[jkl]-*as*-indacene

BY HENRY RAPOPORT AND GERALD SMOLINSKY[1]

RECEIVED MAY 7, 1959

The synthesis of 2,2a,3,3a,4,5-hexahydro-1H-cyclopent[jkl]-*as*-indacene (II) has been achieved by pyrolysis of the lead salt of the appropriate dibasic acid VII and Wolff reduction of the resulting ketone VIII. This tetracyclic hydrocarbon containing three five-membered rings contiguously fused and each fused to the benzene ring shows a marked decrease in the usual aromatic resonance stabilization because of bending in the benzene ring as a result of strain. In its chemical reactivity, it resembles an olefin, being easily hydrogenated, reacting with oxygen of the air ,and rapidly consuming three hundred mole per cent. of perbenzoic acid. The effect of bending a benzene ring on ultraviolet absorption—a distinct bathochromic shift—is clearly demonstrated by comparison of compounds (ketone and hydrocarbon) of this tetracyclic (6,5,5,5) system with the corresponding and identically substituted but unstrained compounds of the hexahydro-*as*-indacene (XXII) system.

Introduction.—The possibility of influencing the resonance stabilization of benzene by forcing a departure from the planarity of the aromatic nucleus has been the subject of much investigation.[2] We have sought to achieve this effect through strain introduced by means of fused five-membered rings. Although statements in the literature predicted otherwise,[3] synthesis of the first member of this series, 2,2a,3,4-tetrahydro-1H-cyclopent[cd]-indene (I), showed that the fused cyclopentane rings had very little effect on the stability of the benzene nucleus other than to markedly increase the ease of catalytic hydrogenation.[2a] A rough calculation[4] using the equations of Howlett[5] and assuming normal bond lengths bore out this result. However, similar calculations made for 2,2a,3,-3a,4,5 - hexahydro - 1H - cyclopent[jkl] - *as* - indacene (II) indicated that this molecule would possess considerable strain. Spurred by this prediction and encouraged by the ease with which the tricyclic (6,5,5) system I had been prepared, the synthesis of the tetracyclic (6,5,5,5) system II was undertaken.[6]



I

Synthesis of 2,2a,3,3a,4,5-Hexahydro-1H-cyclopent[jkl]-*as*-indacene (II).—The synthetic sequence used in preparing the tetracyclic (6,5,5,5) system essentially parallels that used in the pre-

(1) National Science Foundaton Predoctoral Fellow, 1956–1958.

(2) For example, see the following and references therein: (a) H. Rapoport and J. Z. Pasky, THIS JOURNAL, **78**, 3788 (1956); (b) D. J. Cram, N. L. Allinger and H. Steinberg, *ibid.*, **76**, 6132 (1954).

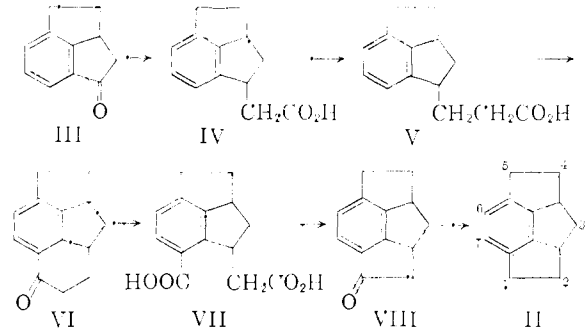
(3) The first eight references cited in ref. 2a.

(4) J. Z. Pasky, Ph.D. Dissertation, University of California, Berkeley, 1956.

(5) K. E. Howlett, *J. Chem. Soc.*, 1249 (1955).

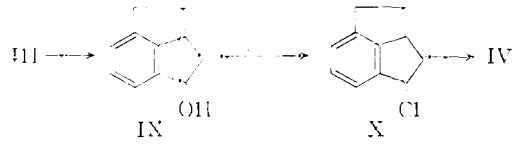
(6) A preliminary report of this work has appeared in THIS JOURNAL, **79**, 5831 (1957).

vious synthesis of the tricyclic (6,5,5) hydrocarbon I.[2a] The principle involved was ring-contraction of the six - membered ring ketone VI, readily prepared through intramolecular acylation of the benzene ring. Contraction was achieved by ring opening to the diacid VII which then was cyclized to the five-membered ring compound VIII by pyrolysis of its lead salt, thus not involving substitution into the benzene ring. The ketone III used as the



starting compound in the synthesis was required in quantity and was prepared as reported previously[2a] with the necessary modifications required by the larger scale of most reactions. Of particular assistance was the construction and use of an apparatus for large-scale vacuum pyrolysis and sublimation.[2g]

The preparation of the acetic acid IV was accomplished by sodium borohydride reduction of the ketone to the corresponding alcohol IX, conversion of alcohol IX to chloride X with anhydrous hydrogen chloride, and condensation of the chloride X with malonic ester. Condensations carried out in boiling *t*-butyl alcohol with potassium *t*-butylate gave poor yields of acid IV with the remainder of the chloride presumably undergoing elimination. However, with sodium isopropylate in isopropyl alcohol at 45° the yield of acetic acid was increased to 80%.

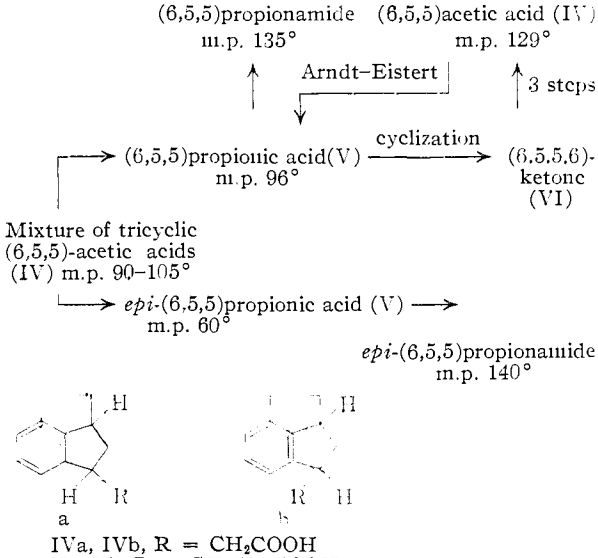


Analytically pure acetic acid IV melted over a range of 15 degrees; the possibility that this was due to polymorphism was eliminated. The alternative explanation for this melting point behavior, the presence of stereoisomers, was established by the reactions described below.

Arndt–Eistert homologation of IV afforded the propionic acid V.[7] Approximately 80% of crude propionic acid could be recovered crystalline from hexane and the remainder was obtained as an oil. The isolation procedure was such that any acetic acid present would have been removed; thus the non-crystalline acid in question must consist entirely of propionic acids, and this was confirmed by the elemental analysis and equivalent weight of the oil.

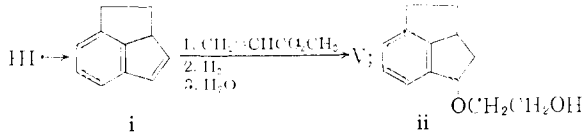
Crystalline propionic acid V (m.p. 96°) was cyclized with hydrogen fluoride in 93% yield to the tetracyclic (6,5,5,6) ketone VI, while non-crystalline acid was ring closed to the extent of only 30–40%. This striking difference in rate of ring closure afforded a means by which the crystalline stereoisomeric propionic acid was obtained.

By repeated partial cyclizations, a fraction of unreacted acid was recovered and this was converted to amide. Chromatography of the amide on alumina gave a tricyclic (6,5,5)propionamide of m.p. 140°. Saponification of this amide afforded the tricyclic (6,5,5)propionic acid (V) of m.p. 60°, and we have called this isomer the *epi*-compound. Homologation of the tricyclic (6,5,5)-acetic acid (IV) (m.p. 129°) obtained from the lead salt pyrolysis, discussed below, yielded tricyclic (6,5,5)propionic acid (V) of m.p. 96°. In the following chart the relationships among the various compounds are summarized. Mixed melting point determinations with the two amides and two propionic acids each showed marked depressions, while the several compounds containing the tricyclic (6,5,5) system (acetic acids, propionic acids and amides) all have practically identical ultraviolet absorption with maxima in the regions 268–271 mμ (ε 742–773) and 276–278 mμ (ε 690–702).



IVa, IVb, R = CH_2COOH
Va, Vb, R = CH_2CH_2COOH

(7) An alternative method of obtaining propionic acid V, from ketone III, utilizing the Bamford–Stevens reaction[8] to obtain the olefin i was considered, however, when the *p*-toluenesulfonylhydrazone of III was subjected to this reaction, the only product obtained was the monoglycol ether, ii. It is noteworthy that Pasky also found this reaction to give only monoglycol ether in the attempted conversion of 2a,3,4,5-tetrahydro-5-acenaphthenone to 2a,3-dihydroacenaphthene.[4]



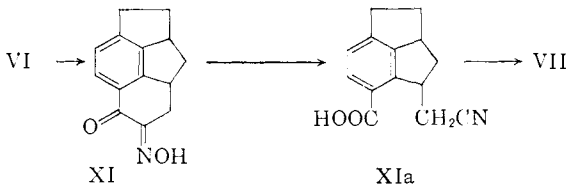
Furthermore, Rapoport and Tretter[9] report monoglycol ether formation in the attempted conversion of 1-ketolilolidine to liloline. Bamford and Stevens carried out their reaction with only one benzocycloalkanone; they obtained a 92% conversion of indanone to indene. Monoglycol ethers were obtained only with those ketones incapable of forming olefins. However, in view of the other examples given above, this does not appear to be a reliable method for converting benzocycloalkanones to olefins.

(8) W. R. Bamford and T. S. Stevens, *J. Chem. Soc.*, 4735 (1952).

(9) H. Rapoport and J. R. Tretter, *J. Org. Chem.*, **23**, 248 (1958).

Even though there is a marked difference in the cyclization rates of the two propionic acids to the ketone VI, it is not possible to decide from an examination of models which geometry, Va or Vb, would lead to more facile ring closure.

Ketone VI was nitrosated to the α-oximinoketone XI and the second-order Beckmann rearrangement of XI led to the ring-opened cyanoacid XIa. Alkaline hydrolysis of XIa gave the diacid VII, the lead salt of which was pyrolyzed



XI XIa

in vacuum in the large-scale sublimer.[29] Three products were obtained from the pyrolysis, *viz.*, the desired tetracyclic (6,5,5,5) ketone VIII in 3% yield, an unstable hydrocarbon in 6% yield, and an acid in 20% yield.

The hydrocarbon had an empirical formula $C_{12}H_{12}$, and its ultraviolet spectrum (λ_{max}^{hexane} 255 mμ, ε 8740) is consistent with either structure XIIa or XIIb. From the reaction of this hydrocarbon

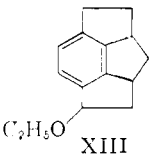
XIIa XIIb

with osmium tetroxide a crude product was obtained which was subjected to periodate oxidation. Since no formaldehyde could be detected, the evidence, although negative, favors structure XIIb.

The pyrolysis-acid proved to be one of the stereoisomers of the tricyclic (6,5,5)acetic acid IV (m.p. 129°, see chart above). Its structure was established by (a) an examination of its ultraviolet spectrum in neutral and alkaline ethanolic solution, which proved the absence of any substituted benzoic acid, (b) elemental analysis, (c) equivalent weight determination and (d) its infrared spectrum which is identical with that of the mixture of stereoisomeric acetic acids IV. Final proof was provided by homologation of this acid to the tricyclic (6,5,5)propionic acid V of m.p. 96°.

The last step in the synthesis was conversion of the tetracyclic (6,5,5,5) ketone VIII to the hydrocarbon II and the best procedure appeared to be Wolff reduction[10] of the semicarbazone. This process offered the advantage of further purification through the isolated semicarbazone and had promise for a purer hydrocarbon than the one-step method (hydrazine and potassium hydroxide on the ketone). The procedure to be used was first developed on the more plentiful tetracyclic (6,5,5,6) ketone VI, taking cognizance of the results of Dutcher and Wintersteiner[11] who found that alcohols were often obtained from Wolff reductions of steroidal ketones if the solvent (usually ethanol) was wet and if insufficient hydrazine was added along with the semicarbazone. Accordingly, the reduction of the semicarbazone of ketone VI was carried out in a sealed tube in absolute ethanol with sodium ethylate and in the presence of several hundred mole per cent. excess anhydrous hydrazine[12]; the tetracyclic (6,5,5,6) hydrocarbon VIa was obtained in 89% yield.

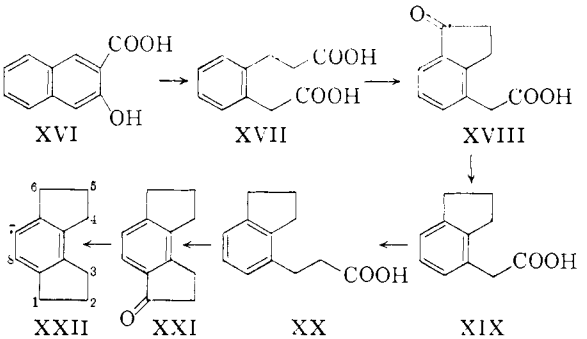
When the semicarbazone of the tetracyclic (6,5,5,5) ketone VIII was subjected to the above reaction conditions, the reduction product proved to be quite complex. The volatile material, *i.e.*, material which would sublime at 75° (20 mm.), was found to consist of a mixture of products in which ethoxyl-containing material was present and which appeared to be composed of about 30% of the ether XIII. It was not possible to effect a purification of this mixture due to the rapidity with which



XIII

the material reacted with air. This extreme reactivity with oxygen made it imperative to find reduction conditions which would lead directly to a pure product. Since the major side reaction was ether formation, the use of potassium *t*-butylate and *t*-butyl alcohol (in place of ethanol) should eliminate this impurity. This proved to be the case, and in this system the tetracyclic (6,5,5,5) hydrocarbon II was prepared essentially free of side products. The use of *t*-butyl alcohol in this reduction, which we have not encountered previously, appears to have distinct advantages over the customarily used ethanol.

Synthesis of 1,2,3,6,7,8-Hexahydro-*as*-indacene (XXII).—This compound is obviously the best model with which to compare the physical and chemical properties of the tetracyclic (6.5,5,5) hydrocarbon II. The electronic effects due to substitutents on the benzene nucleus must be the same in both compounds, and thus differences in properties of the aromatic ring must be the result of strain imposed by the methano bridge of the 2a- and 3a-positions in II. The synthetic approach to XXII outlined below was chosen as much for the fact that it allowed for the preparation of ketone XXI, an excellent model compound for the tetracyclic (6,5,5,5) ketone VIII, as for the availability of starting material XVI.



XVI XVII XVIII XIX XX XXI XXII

(10) D. Todd in "Organic Reactions," Vol. IV, John Wiley and Sons, Inc., New York, N. Y., 1948, p. 378.

(11) J. D. Dutcher and O. Wintersteiner, THIS JOURNAL, **61**, 1992 (1939).

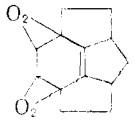
(12) L. I. Smith and K. L. Howard, *Org. Syntheses*, **24**, 53 (1944).

O-(Carboxymethyl)-hydrocinnamic acid (XVII) was obtained by sodium–alcohol reduction of 3-hydroxy-2-naphthoic acid (XVI) following the directions of Fry and Fieser.[13] An attempt at cyclization of XVII to ketoacid XVIII with hydrogen fluoride gave poor results; however, the use of polyphosphoric acid as the acylating catalyst proved quite successful. The diacid XVII and the ketoacid XVIII are quite soluble in water, and thus a clean-cut separation is difficult; however, catalytic reduction of the keto group in XVIII, at room temperature and atmospheric pressure with palladium-on-carbon as catalyst, yielded 4-indanacetic acid (XIX) which was readily obtained pure from methanol–water solutions.

Arndt–Eistert homologation of XIX to 4-indanpropionic acid (XX) was followed by ring closure using polyphosphoric acid to give ketone XXI. Catalytic hydrogenation was used again to convert the carbonyl group to methylene, and ketone XXI afforded hydrocarbon XXII.[14]

Chemical Properties of the Tetracyclic (6,5,5,5) System.—A qualitative indication of the increased strain in the 6,5,5,5-system was immediately apparent from the contrast in yield of the tricyclic (6,5,5) ketone III with that of the tetracyclic (6,5,5,5) ketone VIII formed on pyrolysis of the appropriate lead salts. The former was obtained in 35% yield,[2a] the latter in only 3%. Conclusive evidence of the decrease in resonance energy of the tetracyclic (6,5,5,5) system was manifest in the chemical properties of hydrocarbon II, especially when compared with those of tricyclic compound I and XXII.

Hydrocarbon II, on exposure to air at room temperature, hardens to a glass-like film with accompanying loss of its strong, sweet, camphoraceous odor. This material was found to have absorbed 10% by weight of oxygen after two days and 15% after seven days. Furthermore, the ultraviolet spectrum of this substance in ethanol exhibits no aromatic absorption but instead reveals a maximum at 209 mμ with an estimated extinction coefficient of 15,000–20,000. These facts are consistent with the formation of some such compound as XXIII, retaining a tetrasubstituted double bond. In contrast, hydrocarbons I and XXII are completely stable toward air oxidation.



XXIII

As in the case of the 6,5,5-hydrocarbon I, the 6,5,5,5-hydrocarbon II in methanol was found to absorb 300 mole per cent. of hydrogen when shaken with 5% palladized carbon at room temperature in an atmosphere of hydrogen. Hydrocarbon XXII was completely stable toward hydrogenation under these conditions. The ultraviolet spectrum of the perhydro-6,5,5,5-compound shows no absorption in the region from 220 to 350 mμ (2×10^{-3} molar in hexane).

At room temperature in chloroform, II consumed 300 mole per cent. of perbenzoic acid and a diepoxyhydroxybenzoate was isolated. In comparative experiments both hydrocarbons I[2a] and XXII were almost completely unreactive.

Table I summarizes some chemical properties of the three hydrocarbons I, II and XXII. The *as*-hydrindacene XXII provides a model polyalkylbenzene and shows the expected aromatic stability in all three reactions. It is apparent that in compound I some modification of the aromatic resonance stabilization has occurred as manifest by its facile reduction on catalytic hydrogenation; however, no other evidence of increased reactivity due to strain could be found. In contrast, the tetracyclic (6,5,5,5) hydrocarbon II appeared almost olefinic in its reactivity with oxygen, hydrogen and perbenzoic acid. This can only be the result of a significant decrease in resonance energy caused by bending of the benzene ring in response to the strain imposed by the three fused five-membered rings.

TABLE I

CHEMICAL PROPERTIES OF CYCLOPENTINDENE SYSTEMS

Reaction Compound	With O_2 (air)	Hydrogenation	$C_6H_5CO_3H$ Consumption
I	Stable[2a]	3 moles[2a]	Very slow[2a]
II	Reacts	3 moles	3 moles-rapid
XXII	Stable	No reacn.	Very slow

Spectra.—Since bending a benzene ring would be expected to cause discernible changes in its absorption, a detailed spectral examination has been made of both the ketones and hydrocarbons in this series. In the infrared, in chloroform solution, the positions of the carbonyl bands of the three ketones, the (6,5,5,6) VI (5.95 μ), the (6,5,5,5) VIII (5.88 μ) and the oxo-*as*-hydrindacene XXI (5.87 μ), are as expected for benzcycloalkanones.[15] The fact that in both compounds VIII and XXI the position of the absorption maximum is essentially identical indicates that in these compounds in the ground state the environment of the keto group is quite similar.

Examination of the ultraviolet absorption of these compounds is much more revealing. Many investigators[16] have pointed out that altering the degree of planarity of two conjugated chromophores can produce either a hypsochromic or bathochromic shift in the position of the K-band[17] of the system. The literature is replete with examples of hypsochromic effects, the case of the sterically hindered biphenyls having been

(13) E. M. Fry and L. F. Fieser, THIS JOURNAL, **62**, 3489 (1940).

(14) An alternative method for preparing hydrocarbon XXII came to our attention in the paper by V. R. Skvarchenko, R. Ya. Levina, and O. Ya. Okhlobystin, *Doklady Akad. Nauk S.S.S.R.*, **99**, 789 (1954). However, the desired ketone intermediate XXI is not available from this procedure which involves Diels–Alder addition of maleic anhydride to 1,1,-dicyclopentenyl followed by the action of phosphorus pentoxide on the adduct to give XXII

(15) R. N. Jones and C. Sandorfy in A. Weissberger, "Technique of Organic Chemistry," Vol. IX, Interscience Publishers, Inc., New York, N. Y., 1956, pp. 443–509.

(16) (a) E. Heilbronner and R. Gerdil, *Helv. Chim. Acta*, **39**, 1996 (1956); G. W. Wheland, "Resonance in Organic Chemistry," John Wiley and Sons, Inc., New York, N. Y., 1955, p. 314 ff.; (c) G. N. Lewis and M. Calvin, *Chem. Revs.*, **25**, 273 (1939).

(17) A. E. Gillam and E. S. Stern, "An Introduction to Electronic Absorption Spectroscopy in Organic Chemistry," Edward Arnold Ltd., London, 1955, p. 113.

particularly thoroughly studied.[18] On the other hand, unequivocal examples of the bathochromic effect are hard to find.

Moore and Fisher[19] found a red shift of 12 to 18 mμ of the K-band in pinenes having part of the chromophoric system included in a bicyclo[3,1,1]-heptyl ring. They attributed this apparent shift to the strain introduced in the π-system by the bicyclic nature of the molecule. Unfortunately, this shift is a calculated value and depends upon correlations[20] which were made from quite differently constituted molecules.

Di-*p*-xylylene is a compound which clearly contains bent benzene rings, as demonstrated by X-ray diffraction studies,[21] but it has not been possible to separate the effects of interaction between the rings from those due to bending of the rings as far as ultraviolet absorption is concerned.[2b] The same difficulty undoubtedly obtains with di-*m*-xylylene[22] and di-(pyridine-2,6-dimethylene),[23] both of which contain bent aromatic rings. In the latter compound a bathochromic shift of 8 mμ is observed for the maximum when compared with a series of 2,6-dialkylpyridines, but again this cannot be assigned to the effect of bending alone.

In an attempt to eliminate interstitial interactions, a series of *para*-bridged benzene derivatives was prepared containing only one benzene ring.[2b] However, it is very difficult to determine if any warping of the benzene ring was achieved in these compounds. The effects are very small, although what tendency there is appears to be toward a bathochromic shift.

An extensive investigation of steric inhibition of resonance in azulene aldehydes and ketones has been published by Heilbronner and Gerdil.[16a] The spectra of azulene derivatives are quite complex and alkyl substituents alone produce shifts in the maxima to longer or shorter wave lengths. Due to the sensitivity of the absorption to any kind of substitution on the aromatic nucleus, direct measurements of $\Delta\lambda_{max}$ could not be made since no one compound could be used as the model standard absorbing system.

The work with the azulenes provides an example of one of the difficulties encountered in work which attempts to measure the effect of non-planarity of the π-system on the position of the K-band, namely, that in order to introduce the steric factor a substituent is placed on the π-system. Unfortunately, the effect on the absorption due to the added substituent alone usually cannot be determined.

A case in which no extraneous substituents have been introduced on the chromophoric system is found in the benzocycloalkanones presented in Table II. It is seen that as the cycloalkanone ring becomes larger, and thus farther from a planar conformation, there is a tendency of the position of the K-band to move to longer wave lengths. Up to now, this appears to be the best evidence of an observed bathochromic shift which can be attributed solely to steric inhibition of resonance.

TABLE II

POSITION OF THE K-BAND OF SOME BENZYLCYCLOALKANONES[a]

Compound	K-Band λ_{max}, mμ	K-Band ϵ_{max}
o-Methylacetophenone[b]	242	8,500
1-Indanone[c]	244	11,200
1-Tetralone[c]	248	11 600
1-Benzcycloheptanone[d]	246	8,100
1-Benzcyclooctanone[d]	247	6,500

[a] Spectra taken in alcohol solution. [b] Ref. 18a. [c] Ref. 4. [d] R. Huisgen, W. Rapp, I. Ugi, H. Walz and E. Mergenthaler, *Ann.*, **586**, 1 (1954).

An examination of the ultraviolet spectra of the ketones prepared in the cyclopentindene series (Fig. 1) provides another interesting example of a bathochromic shift. It is seen that as strain is introduced in the benzene ring of the ketones listed in Table III, the $\Delta\lambda_{max}$ between the cyclopentanone

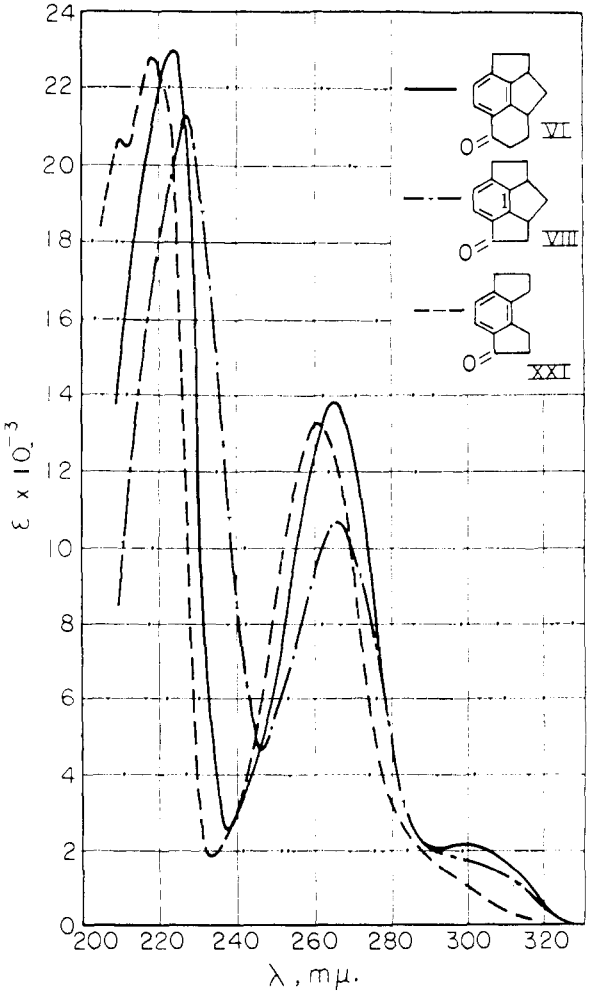


Fig. 1.—Ultraviolet absorption spectra in 95% ethanol.

(18) (a) E. A. Braude, *Experientia*, **11**, 457 (1955); (b) E. A. Braude, F. Sondheimer and W. F. Forbes, *Nature*, **173**, 117 (1954); (c) M. T. O'Shaughnessy and W. H. Rodebush, THIS JOURNAL, **62**, 2906 (1940).

(19) R. N. Moore and G. S. Fisher, *ibid.*, **78**, 4362 (1956).

(20) (a) L. K. Evans and A. E. Gillam, *J. Chem. Soc.*, 565 (1943); (b) R. B. Woodward, THIS JOURNAL, **63**, 1123 (1941); (c) **64**, 76 (1942).

(21) C. J. Brown, *J. Chem. Soc.*, 3265 (1953).

(22) C. J. Brown, *ibid.*, 3278 (1953).

(23) W. Baker, K. M. Buggle, J. F. W. McOmie and D. A. M. Watkins *ibid.*, 3594 (1958).

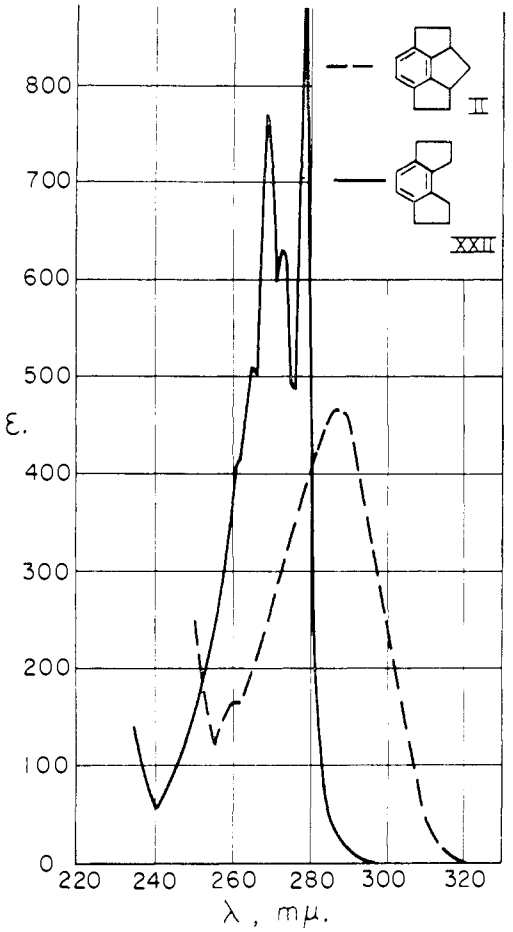
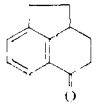


Fig. 2.—Ultraviolet absorption spectra in hexane.

derivative and cyclohexanone derivative in each series (bicyclic, tricyclic, tetracyclic) becomes smaller until in the case of the tetracyclic (6,5,5,5) ketone VIII the λ_{max} is at *longer* wave lengths than the corresponding tetracyclic (6,5,5,6) ketone VI. The marked bathochromic shift of the K-band of the 6,5,5,5-ketone VIII over that of ketone XXI also is worthy of note.

TABLE III

POSITION OF THE K-BAND IN THE ULTRAVIOLET SPECTRA OF SEVERAL INDANONES AND TETRALONES[a]

Compound	K-Band λ_{max}, mμ	K-Band ϵ_{max}
1-Indanone[b]	244	11,200
1-Tetralone[b]	248	11,600
6,5,5-Ketone III[c]	250	11,200
6,5,6-Ketone[c] 	252	12,750
6,5,-,5-Ketone XXI	261	13,310
6,5,5,5-Ketone VIII	267	10,780
6,5,5,6-Ketone VI	266	13,860

[a] Spectra taken in alcohol solution. [b] Ref. 4. [c] Ref. 2a.

It seems safe to generalize that non-planarity involving two absorbing systems usually leads to a hypsochromic shift (biphenyls).[18] Since the molecule is not strained, only non-planar, there is very little change in the energy of the ground state compared to that of the non-hindered model. However, the excited state should be much closer to planarity and this is of higher energy when there are steric effects opposing this planarity. Thus, the electronic transition is a higher energy one and therefore occurs at shorter wave lengths. When the molecule is strained as well as non-planar, there is a larger energy increase in the ground state relative to the excited state, hence a lower energy transition and a bathochromic shift. In the case of the 6,5,5,5-system, the aromatic π-system is under strain and the latter situation pertains.

It was anticipated that the ultraviolet spectra of hydrocarbons II and XXII would be of more value in revealing a difference in the nature of the benzene nucleus of the 6,5,5,5-system than that of the corresponding ketones, since in the hydrocarbons the strong interaction of the carbonyl group and the benzene ring is absent. Indeed a marked difference is found as shown in Fig. 2. The spectrum of hydrocarbon XXII has a maximum extinction coefficient of 896 and much finer structure while the spectrum of II is completely devoid of fine structure, has a maximum extinction of 470, and shows a bathochromic shift of at least 8 mμ. Furthermore, it should be noted that all the tri- and tetrasubstituted benzene derivatives listed in Table IV exhibit some fine structure in their ultraviolet absorption except for compounds II and VIa.

TABLE IV

ULTRAVIOLET ABSORPTION SPECTRA OF SOME TRI- AND TETRASUBSTITUTED BENZENES

Compound	Solvent	$\lambda_{max.}$ mμ	ϵ_{max}
6,5,5-Hydrocarbon I[a]	EtOH	269	691
		277	633
6,5,6-Hydrocarbon[a]	EtOH	266	744
		275	710
as-Hydrindacene (XXII)	Heptane	279[b]	896
1,2,3,4,5,6,7,8-Octahydrophenanthrene[c]	EtOH	273[b]	406
1,2,3,4-Tetramethylbenzene[d]	Isoöctane	268[b]	286
6,5,5,5-Hydrocarbon II	Hexane	287	470
6,5,5,6-Hydrocarbon VIa	Hexane	271	325

[a] Ref. 2a. [b] The maximum of highest extinction coefficient. [c] R. A. Friedel and M. Orchin, "Ultraviolet Spectra of Organic Compounds," John Wiley and Sons, Inc., New York, N. Y., 1951, No. 15. [d] Am. Petr. Inst., Research Proj. No. 44, serial No. 129.

The pronounced difference in absorption between II and XXII can be attributed only to the strain (and warping) imposed on the benzene nucleus by the additional fused cyclopentano ring system since the electronic effects of the alkyl substituents on the benzene ring must be essentially the same in both compounds. Thus the tetracyclic (6,5,5,5) hydrocarbon II provides a definitive example of the effect of bending a benzene ring on its ultraviolet absorption, *viz.*, the elimination of fine structure[24] and an accompanying bathochromic shift and decreased extinction coefficient.

(24) L. L. Ingraham in M. S. Newman, "Steric Effects in Organic Chemistry," John Wiley and Sons, Inc., New York, N. Y., 1956, p. 500.

Experimental[25]

1-Keto-2,2a,3,4-tetrahydro-1H-cyclopent[cd]indene (III).—This tricyclic ketone was prepared substantially as previously reported.[2a] A few changes and improvements were made to accommodate the much larger scale of operation, and these are described briefly below.

Ring closure to **2a,3,4,5-tetrahydro-5-acenaphthenone** was effected by the action of hydrogen fluoride on the acid rather than with aluminum chloride and the acid chloride. From 50 g. of 1-indanpropionic acid in 200 g. of anhydrous hydrogen fluoride, allowed to stand at room temperature as the hydrogen fluoride evaporated overnight, there was obtained a quantitative yield of 2a,3,4,5-tetrahydro-5-acenaphthenone, m.p. 83–85°.

Purification of the crude 7-carboxy-1-indanacetic acid proceeded through esterification in methanol with sulfuric acid and distillation of the **methyl 7-carbomethoxy-1-indanacetate**, b.p. 130° (0.3 mm.), m.p. 54–55°.

Anal. Calcd. for $C_{14}H_{16}O_4$: C, 67.7; H, 6.5; OCH_3, 25.0. Found: C, 67.4; H, 6.6; OCH_3, 25.3.

Saponification of the diester gave pure 7-carboxy-1-indanacetic acid which was converted to the lead salt and the latter was pyrolyzed in 150-g. batches in a specially designed sublimation apparatus.[29] For this purpose, the lead salt was spread evenly over the bottom of a 6.5-in. diameter low-walled (0.5 in.) dish which was placed in the sublimation apparatus and heated rapidly to 400–450° in a nitrogen atmosphere at 30–35 mm. pressure. After 5 hr. the temperature was allowed to fall to 40°, the nitrogen pressure was increased to atmospheric, and the dark, yellowish solid which had sublimed to the cold condensing surface was removed and was resublimed at 60° (20 mm.); yield 21 g., 35%, of almost colorless 1-keto-2,2a,3,4-tetrahydro-1H-cyclopent[cd] indene, m.p. 65° (reported[2a] m.p. 63°).

The *p*-toluenesulfonylhydrazone was prepared by boiling a solution of 2 g. of the ketone III and 4.4 g. of *p*-toluenesulfonylhydrazine[26] in abs. ethanol for two hours. Cooling gave crystals of the hydrazone which were recrystallized from abs. ethanol; yield 3.8 g., 85%, m.p. 196–197°.

Anal. Calcd. for $C_{18}H_{18}O_2N_2S$: C, 66.3; H, 5.6; S, 9.8. Found: C, 66.3; H, 5.8; S, 9.5.

1-(2-Hydroxyethoxy)-2,2a,3,4-tetrahydro-1H-cyclopent[cd]indene.—The *p*-toluenesulfonylhydrazone of ketone III (1 g.) in 30 ml. of a 1 *M* sodium-in-ethylene glycol solution was maintained at reflux in a nitrogen atmosphere for 24 hr. after which time the cooled reaction mixture was diluted with 100 ml. of water and extracted with five 50-ml. portions of benzene. Evaporation of the combined benzene extracts and distillation of the residue at reduced pressure (b.p. 155–185° (10 mm.)) gave 1-(2-hydroxyethoxy)-2,2a,3,4-tetrahydro-1H-cyclopent[cd]indene, characterized as its *p*-nitrobenzoate, m.p. 102–103°.

Anal. Calcd. for $C_{20}H_{19}O_5N$: C, 68.0; H, 5.4. Found: C, 68.3; H, 5.4.

1-Hydroxy-2,2a,3,4-tetrahydro-1H-cyclopent[cd]indene (IX).—Sodium borohydride (19 g., 0.5 mole) in 100 ml. of 50% aqueous methanol was added in small portions to a stirred solution of 9.1 g. (0.058 mole) of the tricyclic ketone III in 50 ml. of methanol. After standing 24 hr. at room temperature, the reaction solution was heated on the steam-bath for 0.5 hr. with 4 g. of sodium hydroxide dissolved in 6 ml. of water. Addtion of an equal volume of water caused the precipitation from this warm solution of 8.6 g. of material, and extraction of the filtrate with methylene chloride gave an additional 0.3 g. of alcohol. Sublimation (100° (5 mm.)) of the crude alcohol gave 8.7 g. (94%) of material of m.p. 80–83°. For analysis, this material was recrystallized from aqueous methanol and then sublimed, m.p. 87.7–88.1°; λ_{max}^{hexane} 269 mμ (ε 754), 277 (716).

Anal. Calcd. for $C_{11}H_{12}O$: 82.5; H, 7.8. Found: C, 82.5; H, 7.6.

1-Chloro-2,2a,3,4-tetrahydro-1H-cyclopent[cd]indene (X).—Anhydrous hydrogen chloride was bubbled through a solution of 6.6 g. (0.037 mole) of 1-hydroxy-2,2a,3,4-tetrahydro-1H-cyclopent[cd] indene (IX) in 60 ml. of dry ether at 0° for 6 hr. The saturated ethereal hydrogen chloride solution was allowed to stand overnight, after which time it was washed cautiously with water and dried. The ether was removed at reduced pressure at 25°, the final pressure being 0.1 mm., leaving a residue of 7.1 g., 96%, of pure chloride. A distilled sample of chloride (b.p. 135° (10 mm.)) had $n^{25}D$ 1.5792.

Anal. Calcd. for $C_{11}H_{11}Cl$: C, 73.9; H, 6.2; Cl, 19.9. Found: C, 73.8; H, 6.2; Cl, 19.8.

2,2a,3,4-Tetrahydro-1H-cyclopent[cd]-1-indeneacetic Acid (IV).—Diethyl malonate (32.4 g., 0.20 mole) in 25 ml. of dry isopropyl alcohol was added to a stirred solution of sodium (2.56 g., 0.11 mole) in 280 ml. of isopropyl alcohol under a nitrogen atmosphere and maintained at 45°. To this solution was added dropwise 18.3 g. (0.10 mole) of the chloride X, and after addition was completed (15 min.), the reaction solution was stirred and maintained at 45° for 18 hr. Following removal of the isopropyl alcohol by distillation, the alkaline residue was acidified with 50 ml. of 1 *N* hydrochloric acid and this mixture was extracted with three 25-ml. portions of methylene chloride. The combined organic extracts were washed with 1 *N* carbonate, dried, and concentrated at reduced pressure. Distillation gave 26.9 g. of diester, b.p. 148° (0.3 mm.), $n^{24}D$ 1.5151.

Anal. Calcd. for $C_{18}H_{22}O_4$: C, 71.5; H, 7.3. Found: C, 71.2; H, 7.2.

Saponification of the diester was accomplished by boiling it in a nitrogen atmosphere with 150 ml. of 4 *N* 50% aqueous ethanolic potassium hydroxide for 17 hr. After removal of the ethanol by distillation, the alkaline solution was acidified with concentrated hydrochloric acid, the diacid was extracted with ether and the organic phase was dried and evaporated at reduced pressure. Decarboxylation was effected by heating the diacid in a nitrogen atmosphere at 180–190° for 0.5 hr. Sublimation (100–110° (5 μ)) of the residue resulted in 15.2 g. (74%) of the 1-indeneacetic acid IV, m.p. 95–110°; λ_{max}^{EtOH} 269 mμ (ε 773), 277 (694).

Anal. Calcd. for $C_{13}H_{14}O_2$: C, 77.2; H, 7.0; equiv. wt., 202. Found: C, 77.4; H, 7.0; equiv. wt., 202.

Methyl 2,2a,3,4-Tetrahydro-1H-cyclopent[cd]-1-indeneacetate.—A solution of 11.8 g. (0.058 mole) of the 1-indeneacetic acid IV, 2 ml. of concentrated sulfuric acid and 30 ml. of methanol was boiled for 3 hr., then allowed to stand at room temperature for 17 hr. This solution was poured onto a mixture of 10 g. of sodium bicarbonate, 50 ml. of water and 100 g. of ice. The ester was extracted with methylene chloride, and the organic phase was washed with 1 *N* carbonate, dried, and concentrated at reduced pressure. A distillation at reduced pressure through a 3-foot Podbielniak column resulted in 11.9 g. (95%) of ester having a b.p. of 129–131° (2/mm.), $n^{25}D$ 1.5371.

Anal. Calcd. for $C_{14}H_{16}O_2$: C, 77.8; H, 7.5. Found: C, 78.2; H, 7.6.

2,2a,3,4-Tetrahydro-1H-cyclopent[cd]-1-indenepropionic Acid (V).—The 1-indeneacetic acid IV (14 g., 0.07 mole) was treated with purified thionyl chloride[27] (30 ml., 0.41 mole) at room temperature for three hours and the excess thionyl chloride was then removed *in vacuo*. Distillation of the residue gave 14.8 g. (97%) of acid chloride as the fraction boiling at 114–118° (0.5 mm.).

A solution of the acid chloride in 25 ml. of dry ether was added to a stirred solution of diazomethane[28] (6.7 g., 0.16 mole) in 500 ml. of ether which was cooled in an ice-bath. After the yellow solution had been stirred overnight at room temperature, the ether was removed at reduced pressure at 25°. The residual solid, yellow diazoketone was taken up in 150 ml. of methanol and a solution of silver benzoate (3 g.) in 40 ml. of triethylamine was added in small portions with stirring. When no further nitrogen evolution was observed (about two hr.), 5 ml. of saturated sodium chloride was added to the methanolic mixture to precipitate the silver, and this mixture was boiled with a few grams of charcoal, filtered, and the solvent removed at reduced pressure. The residue was dissolved in ether, washed consecutively with 1

(25) All melting points are corrected and those above 150° were taken in evacuated capillaries; microanalyses were performed by the Microchemical Laboratory, University of California, Berkeley. Ultraviolet spectra were taken with a Cary model 11 or 14 ultraviolet recording spectrophotometer. The infrared spectra were taken in chloroform solution with a Baird infrared recording spectrophotometer. Anhydrous sodium sulfate was used as the drying agent unless otherwise stated.

(26) K. Freudenberg and F. Blummel, *Ann.*, **440**, 51 (1924).

(27) D. L. Cottle, THIS JOURNAL, **68**, 1380 (1946).

(28) T. J. DeBoer and H. J. Backer, *Org. Syntheses*, **36**, 16 (1956).

N hydrochloric acid, 1 *N* carbonate, water and a saturated sodium chloride solution. The dried ether phase was concentrated at reduced pressure and the residue was distilled. Crude methyl ester (13.1 g.) was obtained as the fraction boiling at 120–140° (0.3–0.5 mm.), and redistillation through a 3-foot Podbielniak column afforded 12.0 g. (74%) of the **methyl ester of the 1-indenepropionic acid V**, b.p. 127–130° (0.9 mm.), $n^{27}D$ 1.5350.

Anal. Calcd. for $C_{15}H_{18}O_2$: C, 78.2; H, 7.9; OCH_3, 13.5. Found: C, 78.6; H, 7.8; OCH_3 13.6.

Saponification was effected by boiling a solution of the ester in 150 ml. of 4 *N* 50% aqueous ethanolic potassium hydroxide for 16 hr. in an atmosphere of nitrogen. After removing the ethanol by distillation, the alkaline solution was cooled and acidified with concentrated hydrochloric acid and this aqueous mixture was extracted with methylene chloride. The organic phase was dried and the solvent removed at reduced pressure leaving 11.6 g. of a dark red oil which slowly crystallized on standing. A recrystallization from hexane yielded 8.34 g. of the 1-indenepropionic acid V, m.p. 55–75°. For analysis, a sample was recrystallized several times from hexane, m.p. 95.7–96.1°.

Anal. Calcd. for $C_{14}H_{16}O_2$: C, 77.8; H, 7.5; equiv. wt., 216. Found: C, 77.7; H, 7.4; equiv. wt., 214.

2,2a,3,4-Tetrahydro-1H-cyclopent[cd]-1-indenepropionamide.—The 1-indenepropionic acid V, (1.36 g., 6.3 moles) was converted to its acid chloride by dissolution in 10 ml. of purified[27] thionyl chloride, and the solution was allowed to stand at room temperature for about an hour, after which the excess thionyl chloride was removed at reduced pressure. The residual acid chloride, dissolved in 10 ml. of abs. acetone, was added dropwise with vigorous stirring to 50 ml. of concd. ammonium hydroxide. Immediate precipitation of the amide occurred, and after 15 minutes, 100 ml. of water was added and the mixture was extracted with chloroform. Evaporation of the dried chloroform extracts gave 1.33 g. (98%) of amide which was crystallized several times from benzene and sublimed (140° (0.01 mm.)), m.p. 134–135°; λ_{max}^{EtOH} 269 mμ (ε 742), 277 (700).

Anal. Calcd. for $C_{14}H_{17}NO$: C, 78.1; H, 8.0; N, 6.5. Found: C, 78.3; H, 7.9; N, 6.5.

***epi*-2,2a,3,4-Tetrahydro-1H-cyclopent[cd]-1-indenepropionic Acid and Amide.**—Fractionation of 98.6 g. of methyl 2,2a,3,4-tetrahydro-1H-cyclopent[cd]-1-indenepropionate through a 3-foot Podbielniak column resulted in obtaining 37.6 g. of material boiling at 152° (3 mm.) as a middle fraction. This ester was saponified as described above, and yielded 35 g. of acid which was recrystallized from hexane to give 15.6 g. and 11.7 g. of crystalline acid in successive crops. The remaining acid (7.8 g.) was obtained as an oil. The oily acid (7.8 g., 0.036 mole) was dissolved in 30 g. of anhydrous hydrogen fluoride, and the reaction was stopped after 0.5 hr. by the addition of 50 ml. of a saturated boric acid solution. Extraction with chloroform followed by thorough washing of the chloroform phase with water and *N* carbonate solution gave on evaporation of the chloroform 2.5 g., 36% yield, of the tetracyclic ketone VI (see below). From the carbonate washings, 5.0 g., 63%, of acid was recovered.

The recovered acid, on further treatment with hydrogen fluoride (20 ml.), was found to yield only 0.4 g., 9%, additional ketone VI, and from the carbonate extracts 3.6 g., 73%, of unreacted acid was recovered. This acid was sublimed (75° (0.1 mm.)), and the sublimate (2.4 g.) was converted to the acid chloride with 30 ml. of thionyl chloride. When the acid chloride in 15 ml. of abs. acetone was added to a vigorously stirred solution of concd. ammonium hydroxide (50 ml.), precipitation occurred; and the resulting amide was purified by chromatography on alumina (Merck, acid-washed). The column was prepared with benzene and the amide (394 mg.) was eluted with 10% chloroform–benzene. Crystallization from 2:1 benzene–hexane followed by sublimation (115° (5μ)) gave material of m.p. 140–141°; λ_{max}^{EtOH} 271 mμ (ε 754), 278 (690).

Anal. Calcd. for $C_{14}H_{17}NO$: C, 78.1; H, 8.0; N, 6.5. Found: C, 78.2; H, 7.9; N, 6.5.

A solution of 121 mg. (0.56 mmole) of the amide in 20 ml. of 4 *N* 50% aqueous alcoholic potassium hydroxide was maintained at reflux in a nitrogen atmosphere until the ammonia evolution had ceased, about 14 hr. After removal of the ethanol by distillation, the aqueous mixture was acidified with concd. hydrochloric acid and was extracted with ether. Sublimation (85° (0.01 mm.)) of the residue after evaporation of the ether resulted in the *epi*-2,2a,3,4-tetrahydro-1H-cyclopent[cd]-1-indenepropionic acid, m.p. 58–60°.

Anal. Calcd. for $C_{14}H_{16}O_2$: C, 77.8; H, 7.5; equiv. wt., 216. Found: C, 77.5; H, 7.5; equiv. wt., 219.

6-Oxo-2a,3,3a,4,5,6-hexahydrocyclopent[bc]acenaphthene (VI).—In a polyethylene bottle, 23.9 g. (0.11 mole) of the 1-indenepropionic acid V was dissolved in 100 g. of anhydrous hydrogen fluoride. The solution was allowed to evaporate at room temperature (overnight) and the residue was dissolved in 50 ml. of chloroform. The chloroform solution was washed well with saturated boric acid solution, then with *N* carbonate solution, dried, and evaporated to give crude ketone as a residue which was sublimed (100° (5 μ)); yield 20.5 g., 93%, m.p. 134–136°. For analysis, a sample was recrystallized from methanol–water and then sublimed, m.p. 137–138°; λ_{max}^{EtOH} 224 mμ (ε 23,000), 266 (13,860), 299 (2,143).

Anal. Calcd. for $C_{14}H_{14}O$: C, 84.8; H, 7.1. Found: C, 84.5; H, 7.0.

The *p*-toluenesulfonylhydrazone of the ketone, prepared by the procedure described above, was crystallized from abs. ethanol, m.p. 224–225° dec.

Anal. Calcd. for $C_{21}H_{22}O_2N_2S$: C, 68.8; H, 6.1; N, 7.7. Found: C, 68.5; H, 6.1; N, 7.7.

5-Oximino-6-oxo-2a,3,3a,4,5,6-hexahydrocyclopent[bc]acenaphthene (XI).—A solution of the tetracyclic ketone VI (6.18 g., 0.031 mole) and *n*-butyl nitrite (3.54 g., 0.034 mole) in 100 ml. of dry benzene was slowly added to a stirred, cooled (ice-bath) solution of 1.51 g. (0.039 mole) of potassium in 100 ml. of abs. *t*-butyl alcohol and 50 ml. of dry ether in a nitrogen atmosphere. The resulting dark red solution was allowed to slowly warm to room temperature and then was stirred overnight. After removal of the solvents at room temperature under reduced pressure, the residue was taken up in 200 ml. of water. This solution was washed with three 25-ml. portions of benzene and then treated with carbon dioxide to a *p*H of 7–7.5, precipitating the oximinoketone; pale yellow, needle-like crystals of m.p. 222–225° after recrystallization from methanol–water, yield 72–80%.

Anal. Calcd. for $C_{14}H_{13}NO_2$: C, 74.0; H, 5.8; N, 6.2. Found: C, 73.9; H, 5.7; N, 6.1.

7-Carboxy-2,2a,3,4-tetrahydro-1H-cyclopent[cd]-1-indeneacetic Acid (VII).—Benzenesulfonyl chloride (4.51 g., 0.026 mole) in 25 ml. of pyridine was added dropwise to a stirred, cooled (ice-bath) solution of 5.92 g. (0.023 mole) of oximinoketone XI in 35 ml. of pyridine. The reaction solution was allowed to slowly warm to room temperature, and the stirring was continued overnight. After being carefully acidified with 6 *N* sulfuric acid with cooling in an ice bath, the reaction mixture was extracted with three 50-ml. portions of chloroform, the chloroform was removed under reduced pressure, and the residue was dissolved in 100 ml. of methanol. To this methanolic solution was added 200 ml. of *N* potassium hydroxide, and it was then heated with stirring on the steam-bath, allowing the methanol to evaporate. Sufficient concentrated potassium hydroxide solution was added to achieve 200 ml. of a 4 *N* solution, which was boiled in a nitrogen atmosphere for 8 hours. Cooling and acidifying with concd. hydrochloric acid precipitated crude acidic material which was transferred to a Soxhlet extractor and extracted for several days with ether. Evaporation of the ether extract followed by crystallization of the residue from ethanol–water gave 3.92 g. (68%) of diacid, m.p. 241–245°. The analytical sample was recrystallized three additional times from ethanol–water, m.p. 243–244°.

Anal. Calcd. for $C_{14}H_{14}O_4$: C, 68.3; H, 5.7; equiv. wt., 123. Found: C, 68.2; H, 5.8; equiv. wt., 122.

Pyrolysis of the Lead Salt of Diacid VII.—Following the directions of Rapoport and Pasky,[2a] the lead salt of the tricyclic diacid VII was prepared in essentially quantitative yield.

Anal. Calcd. for $C_{14}H_{12}O_4Pb$: C, 37.2; H, 2.7; Pb, 45.9. Found: C, 37.3; H, 2.9; Pb, 46.0.

A typical pyrolysis was carried out as follows: the sublimation apparatus[29] was charged with 30 g. (0.067 mole) of

(29) This sublimation apparatus consisted of a granular aluminum heating bath, adjustable in height and 8 inches in diameter, centered

the lead salt of diacid VII and evacuated to a pressure of about 0.5 mm. The temperature of the heating bath was slowly raised to and maintained at 150° for about 0.5 hr. in order to degas the salt. Nitrogen was then bled into the system to a pressure of 40–45 mm., and this pressure was maintained for the remainder of the pyrolysis. The salt was then rapidly heated to 450–500° and maintained there for 8 hours, after which the apparatus was allowed to cool overnight. Nitrogen was admitted into the system, the cover was removed, and the sublimate was removed from the condensing surface and dissolved in ether. Extraction of the ether solution with *N* carbonate removed acidic material which was precipitated from the carbonate extracts by acidification. Sublimation (100° (5 μ)) and crystallization from aqueous ethanol gave a pure **2,2a,3,4-tetrahydro-1H-cyclopent[cd]-1-indeneacetic acid** (IV), m.p. 129–130°, λ_{max}^{EtOH} 260 mμ (ϵ 760), 276 (702), unchanged on addition of alkali.

Anal. Calcd. for $C_{13}H_{14}O$: C, 77.2; H, 7.0; equiv. wt., 202. Found: C, 77.3; H, 7.1; equiv. wt., 197.

The neutral material remaining on evaporation of the ether solution was chromatographed on alumina. After a hydrocarbon was eluted with hexane within the first three fractions, ketone was obtained in fractions 10–26 with benzene–hexane (1:4) as eluent. This ketone was sublimed (90° (25 mm.)), crystallized from hexane, and resublimed to give **1-oxo-2,2a,3,3a,4,5-hexahydro-1H-cyclopent[jkl]-*as*-indacene** VIII, m.p. 89–91°; λ_{max}^{EtOH} 227 mμ (ϵ 21,300), 267 (10,780).

Anal. Calcd. for $C_{13}H_{12}O$: C, 84.8; H, 6.6; mol. wt., 184. Found: C, 85.0; H, 6.5; mol. wt., 190 (Rast).

The hydrocarbon XXII obtained from the chromatography was molecularly distilled, λ_{max}^{hexane} 255 mμ (ϵ 8,740).

Anal. Calcd. for $C_{12}H_{12}$: C, 92.3; H, 7.6. Found: C, 92.3; H, 7.8.

From the pyrolysis of a total of 66.8 g. (0.148 mole) of lead salt of the tricyclic diacid VII there was obtained 6.5 g. (22%) of the tricyclic indeneacetic acid IV, 1.24 g. (5.5%) of hydrocarbon XII and 0.85 g. (3.1%) of the tetracyclic ketone VIII.

6-Hydroxy-2a,3,3a,4,5,6-hexahydrocyclopent[bc]acenaphthene (XIV).—Nitrogen was bubbled through a solution of 50 mg. (0.25 mmole) of 6-oxo-2a,3,3a,4,5,6-hexahydrocyclopent[bc] acenaphthene (VI), and 76 mg. (2 mmoles) of sodium borohydride in 7.5 ml. of methanol and 2.5 ml. of water. By following the change in the ultraviolet spectrum of the solution, the reaction was found to be complete within 0.5 hr., and 30 ml. of water was added. Extraction with ether was followed by washing of the ether extracts with 0.1 *M* phosphoric acid and *N* carbonate and drying, after which the ether was removed at reduced pressure. Sublimation (50° (0.01 mm.)) of the residue gave 45 mg. (89%) of the tetracyclic alcohol XIV, m.p. 93–96°, λ_{max}^{hexane} 272 mμ (ϵ 395).

Anal. Calcd. for $C_{14}H_{16}O$: C, 84.0; H, 8.1. Found: C, 83.8; H, 7.9.

1-Hydroxy-2,2a,3,3a,4,5-hexahydro-1H-cyclopent[jkl]-*as*-indacene (XXV).—A sodium borohydride reduction of 50 mg. (0.272 mmole) of 1-oxo-2,2a,3,3a,4,5-hexahydro-1H-cyclopent[jkl]-*as*-indacene (VIII) was accomplished as described above and found to be complete within one hour. The reaction solution was boiled with 1 ml. of *N* sodium hydroxide for 15 minutes and then diluted with 25 ml. of water. The alcohol was isolated as in the case above, and a sublimation (50° (0.01 mm.)) resulted in 29 mg. (57%) of the tetracyclic alcohol XXV, m.p. 93–96°; λ_{max}^{hexane} 255 mμ (ϵ 572), 283 (488).

Anal. Calcd. for $C_{13}H_{14}O$: C, 83.8; H, 7.9. Found: C, 83.9; H, 7.9.

2a,3,3a,4,5,6-Hexahydro[bc]acenaphthene (VIa).—The semicarbazone of the tetracyclic ketone VI was prepared according to the procedure of McElvain[30] and recrystallized from pyridine–water, m.p. 238–240° dec.

Anal. Calcd. for $C_{15}H_{17}N_3O$: C, 70.6; H, 6.7; N, 16.5. Found: C, 70.8; H, 6.5; N, 16.6.

To a solution of 690 mg. (17.7 mmoles) of potassium in 15 ml. of dry *t*-butyl alcohol contained in a cylindrical glass tube was added 200 mg. (0.79 mmole) of tetracyclic ketone VI-semicarbazone, 2 ml. of 100% hydrazine[14] (*ca.* 62 mmoles) and 5 ml. of *t*-butyl alcohol. The tube was sealed and heated with shaking at 185–195° for 12 hr. After being cooled to room temperature, the tube was opened and the contents were removed with the aid of a few ml. of methanol, and the solvents were evaporated at reduced pressure. Water was added to the residue, and this aqueous mixture was extracted with peroxide-free ether. The ether extracts were washed consecutively with *N* hydrochloric acid and *N* carbonate and dried. Sublimation (75° (25 mm.)) of the residue obtained on evaporation of the ether gave 120 mg. (83%) of hydrocarbon ($n^{29}D$ 1.5754) which crystallized after several days, m.p. 51–52°, λ_{max}^{hexane} 271 mμ (ϵ 325).

Anal. Calcd. for $C_{14}H_{16}$: C, 91.2; H, 8.8. Found: C, 91.2; H, 8.9.

2,2a,3,3a,4,5-Hexahydro-1H-cyclopent[jkl]-*as*-indacene (II).—Tetracyclic ketone VIII-semicarbazone was prepared as described above and recrystallized from pyridine–water, m.p. 240–241° dec. Reduction of the semicarbazone prepared from 267 mg. (1.45 mmoles) of ketone VIII was accomplished in a sealed tube as described above, and sublimation of the product gave 176 mg. (71%) of hydrocarbon as a colorless, pleasant smelling liquid, λ_{max}^{hexane} 287 mμ (ϵ 470). It was found that the hydrocarbon II could be safely stored in a stoppered container kept at Dry Ice temperature.

Anal. Calcd. for $C_{13}H_{14}$: C, 91.7; H, 8.3. Found: C, 91.7; H, 8.5.

Hydrogenation of 2,2a,3,3a,4,5-Hexahydro-1H-cyclopent[jkl]-*as*-indacene (II).—A solution of 82 mg. (0.48 mmole) of the tetracyclic hydrocarbon II in 5 ml. of methanol was hydrogenated at room temperature and atmospheric pressure using 24 mg. of 5% palladized carbon as catalyst. After 20 minutes and the consumption of 300 mole % of hydrogen, hydrogen absorption ceased, and the mixture was filtered. The residue obtained on evaporation of the filtrate at reduced pressure was dissolved in ether, and the ether solution was washed with 0.1 *M* phosphoric acid and *N* carbonate and dried. The oily residue obtained on evaporation of the ether was distilled (75° (25 mm.)) to give the perhydro compound as a clear distillate.

Anal. Calcd. for $C_{13}H_{20}$: C, 88.6; H, 11.4. Found: C, 88.6; H, 11.4.

Perbenzoic Acid Oxidation of 2,2a,3,3a,4,5-Hexahydro-1H-cyclopent[jkl]-*as*-indacene(II).—A 9:1 chloroform–benzene solution of perbenzoic acid was prepared according to Braun[31] using the modification of Kolthoff.[32] A solution of 68 mg. (0.4 mmole) of the tetracyclic hydrocarbon II in 5 ml. of 0.366 *M* (1.83 mmoles) perbenozic acid in 9:1 chloroform–benzene was allowed to stand at room temperature in the dark for 18 hr. after which a 50 λ aliquot was removed and titrated with standard thiosulfate. The titration indicated that 1.14 mmoles (285 mole %) of perbenzoic acid had been consumed. After being diluted with ether (30 ml.), the reaction solution was washed with *N* carbonate, dried and evaporated, and the residue (135 mg.) was chromatographed on 8 g. of alumina. Elution with 50% hexane–benzene and finally with benzene gave 75 mg. of material of which 30 mg. sublimed at 115° (0.05 mm.). The ultraviolet spectrum of the sublimate in methanol had three maxima: 231 mμ (ϵ 12,900), 273 (1,000), 282 (800), consistent with

under an 11-inch diameter cooling plate constructed of an aluminum carbide coated stainless steel disk and cooled internally by running water. These rested on a 15-inch steel plate fitted with appropriate vacuum-sealed inlets for vacuum, water, thermocouple and electrical connections. The material to be sublimed was spread over a 6.5-inch diameter shallow glass dish which was then embedded in the aluminum heating bath. The heating and cooling apparatus was covered by a cylinder of steel about 13 inches in diameter and 12 inches high with a welded top and a circular window (made of 3/8 inch Plexiglas) and fitted with "O-ring" seals. Internal lighting allowed for adequate observation of any sublimation in progress. The bath could be heated to about 600° and a vacuum of about 0.01 mm. could be achieved. With this apparatus it was possible to sublime 100–150-g. batches of material.

(30) S. M. McElvain, "The Characterization of Organic Compounds," The Macmillan Co., New York, N. Y., 1945, p. 198.

(31) G. Braun, "Organic Syntheses," Coll. Vol. I, John Wiley and Sons, Inc., New York, N. Y., 1941, p. 431.

(32) I. M. Kolthoff, T. S. Lee and M. A. Mairs, *J. Polymer Sci.*, **2**, 199 (1947).

that of benzoate esters.[33] The infrared spectrum showed absorption at 2.85, 2.91, 5.86, 7.80 and 8.50 μ.

1-Oxo-4-indanacetic Acid (XVIII).—A mixture of 10 g. of *o*-(carboxymethyl)-hydrocinnamic acid (XVII), prepared by sodium and amyl alcohol reduction of 2-hydroxy-3-naphthoic acid,[13] and 260 g. of polyphosphoric acid was stirred vigorously and was maintained at 90–95° for 2.5 hr. While cooling the reaction externally with an ice-bath, 300 g. of cracked ice then was slowly added with stirring. The mixture containing the precipitated ketoacid was extracted continuously with ether and the ketoacid left on evaporation of the ether was recrystallized from water (6.91 g., 75%); m.p. of 151–153°. Further crystallization from water and sublimation (130° (5 μ)) gave material of m.p. 154–155°; λ_{max}^{EtOH} 247 mμ (ϵ 10,530), 291 (2,480).

Anal. Calcd. for $C_{11}H_{10}O_3$: C, 69.5; H, 5.3; equiv. wt., 190. Found: C, 69.3; H, 5.3; equiv. wt., 187.

4-Indanacetic Acid (XIX).—A solution of 11.42 g. (0.06 mole) of 1-oxo-4-indanacetic acid (XVIII) in 200 ml. of abs. ethanol was hydrogenated at room temperature and atmospheric pressure using 2.3 g. of 5% palladized carbon as catalyst. After 8 hr., hydrogen absorption ceased at 94 mole % uptake. The mixture was filtered, the filtrate was evaporated and the residue was recrystallized from methanol–water to give 8.59 g. (81%) of acid, m.p. 101–102°; λ_{max}^{EtOH} 267 mμ (ϵ 869), 275 (894).

Anal. Calcd. for $C_{11}H_{12}O_2$: C, 75.0; H, 6.9; equiv. wt., 176. Found: C, 74.9; H, 6.8; equiv. wt., 175.

4-Indanpropionic Acid (XX).—Indanacetic acid (XIX) (8.57 g., 0.049 mole) dissolved in 35 ml. of purified[27] thionyl chloride was kept at room temperature for 3 hours after which the excess thionyl chloride was removed at reduced pressure. Distillation resulted in 6.88 g. (73%) of 4-indanacetyl chloride as the fraction boiling at 78–80° (0.3 mm.). A solution of this acid chloride in 25 ml. of abs. ether was allowed to react with 4.6 g. (0.11 mole) of diazomethane in 300 ml. of ether as described for the preparation of 2,2a-3,4 - tetrahydro - 1H - cyclopent[cd] - 1 - indenepropionic acid (V), above, and 5.19 g. of methyl 4-indanpropionate was obtained as the fraction boiling at 102–108° (0.6 mm.). Saponification gave 4-indanpropionic acid (4.1 g., 44% over-all yield) which was recrystallized from methanol–water, m.p. 113–114°.

Anal. Calcd. for $C_{12}H_{14}O_2$: C, 75.8; H, 7.4; equiv. wt., 190. Found: C, 75.5; H, 7.3; equiv. wt., 188.

3-Oxo-1,2,3,6,7,8-hexahydro-*as*-indacene (XXI).—4-Indanpropionic acid (XX) (2.11 g., 0.011 mole) and 57 g. of polyphosphoric acid were stirred vigorously and maintained at 95–100° for 1 hour after which 50 grams of ice was added cautiously with stirring to the externally cooled reaction mixture. The aqueous mixture was extracted with ether the ether was washed with *N* carbonate, dried and evaporated, and the residual ketone crystallized from methanol–water in long fine needles; yield 1.65 g. (84%), m.p. 108–109°; λ_{max}^{EtOH} 209 mμ (ϵ 20,650), 218 (22,820), 261 (13,330).

Anal. Calcd. for $C_{12}H_{12}O$: C, 83.7; H, 7.0. Found: C, 83.7; H, 7.1.

The *p*-toluenesulfonylhydrazone of XXI was prepared in the usual manner and crystallized from benzene–ethanol, m.p. 230–231° dec.

Anal. Calcd. for $C_{19}H_{20}O_2N_2S$: C, 67.0; H, 5.9; N, 8.2. Found: C, 66.8; H, 5.9; N, 8.5.

1,2,3,6,7,8-Hexahydro-*as*-indacene (XXII).—A solution of 4.1 g. (0.024 mole) of 3-oxo-1,2,3,6,7,8-hexahydro-*as*-indacene (XXI) in 100 ml. of abs. ethanol was hydrogenated at room temperature and atmospheric pressure with 0.8 g. of 5% palladized carbon as catalyst. After 15 hr. the hydrogen absorption ceased at 92% of the theoretical two-mole absorption. The mixture was filtered, the filtrate was evaporated, and the residue was dissolved in ether. The ethereal solution was washed with *N* carbonate, dried and evaporated, and the solid residue was sublimed, resulting in 3.4 g. (90%) of hydrocarbon of m.p. 40–42° (reported[14] m.p. 39–40°); λ_{max}^{hexane} 265 mμ (ϵ 513), 269 (775) 273 (635) 279 (896).

Anal. Calcd. for $C_{12}H_{14}$: C, 91.1; H, 8.9. Found: C, 90.8; H, 8.9.

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(33) H. E. Ungnade and R. W. Lamb, THIS JOURNAL, **74**, 3789 (1952).

[CONTRIBUTION FROM THE RESEARCH LABORATORIES OF THE UPJOHN CO.]

3-Acylindole Mannich Bases and their Transformation Products

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The Mannich-base reaction of several 3-acylindole derivatives was studied and in two cases the formation of bis-Mannich bases (X and XII) was observed. Several reactions of the bases were explored which included lithium aluminum hydride and sodium borohydride reduction of VI. The alcohol XIII was dehydrated to the vinylog of gramine XV. The Mannich base methiodide XVII underwent displacement with sodium cyanide to give the ketocyanide XVIII and elimination with sodium bicarbonate to give the vinylketone XX.

The reaction which is known in the literature as the "Mannich Base Condensation" has been reviewed by Blicke[1] and Hellman[2] and several mechanisms have been suggested.[3,4]

We have undertaken the present work with two objectives in mind. First, we have been interested in the indole field from the standpoint of biological activity and it was hoped that the Mannich base reaction would afford versatile intermediates in this respect. Secondly, we were interested in studying the results of the Mannich base condensation in a case where one could vary the alkyl substitution on the carbon adjacent to the reaction site and also on the indolic nitrogen.

The 3-acetylindole molecule (I) seemed to be a good candidate for this study. The carbonyl function gives rise to the hybrid formulated as I, in which ketonic and vinylogous amide structures contribute. The chemical and physical properties of this system correlate well with the properties expected from this formulation. Thus, 3-acetylindole forms a phenylhydrazone,[5] a hydrazone,[6] an oxime[7] and a thiosemicarbazone.[8] On the other

(1) F. F. Blicke, "Organic Reactions," Vol. I, John Wiley and Sons, Inc., New York, N. Y., 1942, p. 303.

(2) H. Hellmann, *Angew. Chem.*, **65**, 473 (1953).

(3) H. Hellmann and G. Opitz, *ibid.*, **68**, 265 (1956); H. Hellmann and G. Opitz, *Ber.*, **89**, 81 (1956); H. Hellmann and O. Schumacher, *ibid.*, **89**, 95 (1956); E. C. Wagner, *J. Org. Chem.*, **19**, 1862 (1954); E. R. Alexander and E. J. Underhill, THIS JOURNAL, **71**, 4014 (1949).

(4) S. V. Liebermann and E. C. Wagner, *J. Org. Chem.*, **14**, 1001 (1949).

(5) B. Oddo and L. Sessa, *Gazz. chim. ital.*, **41**, 234 (1911).

(6) C. Alberti, *ibid.*, **77**, 398 (1947).

(7) Ramart-Lucas and M. Rocli, *Compt. rend.*, **232**, 843 (1951).

(8) G. Tsatsas, *ibid.*, **235**, 175 (1952).