[CONTRIBUTION FROM THE DEPARTMENT OF CHEMISTRY, UNIVERSITY OF WASHINGTON]

Azulene. VII. A Study of the Beckmann Rearrangement of 1,3-Diacetylazulene Dioxime and 1,3-Diacetylazulene Dioxime Diacetate[1,2]

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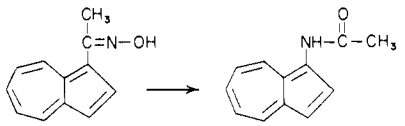
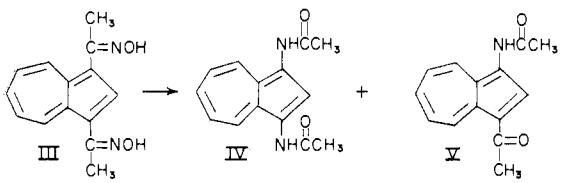
The preparations of the dioxime and the dioxime diacetate of 1,3-diacetylazulene are described. Studies on the rearrangement of the dioxime and two geometric isomers of the dioxime diacetate are presented which include the characterization of all of the major products formed, considerations of how these arose, and an assignment of the configurations of the isomeric dioxime diacetates as *anti–anti* and *syn–anti* with reference to the azulene ring. The visible absorption spectra of the new 1,3-disubstituted azulenes are tabulated and generally found to agree with Plattner's rule.

In earlier work[3] it was found that the oxime of 1-acetylazulene (I) could be prepared readily and Beckmann rearrangement of this compound with phosphorus pentachloride gave 1-acetamidoazulene (II) in low (16%) yield. There was considerable decomposition during the rearrangement reaction and the only other simple product obtained appeared to be 1-acetylazulene, presumably formed by hydrolysis of unrearranged oxime during the work-up. This result could be interpreted in several ways: that only one form of the oxime was obtained (the derivative melted sharply), that one form rearranges and the other hydrolyzes, or that the N-methylamide product is unstable, etc. In any event, the fact that only one rearrangement product was obtained led to consideration of the method as one means of preparing the 1,3-diacetamide derivative IV, a possible intermediate in the synthesis of the corresponding diamine.



I II

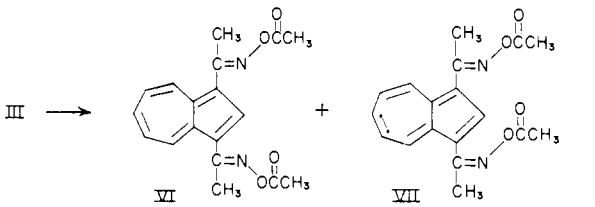
Accordingly, the dioxime of 1,3-diacetylazulene (III) was prepared (82%) and, as with I, only one form was isolated. Treatment of III (a green solid) with phosphorus pentachloride in absolute ether gave *two* new products plus a small amount of the diacetylazulene. The products, obtained in 21 and 25% yield, respectively, proved to be 1,3-diacetamidoazulene (IV) and 1-acetamido-3-acetylazulene (V), which had been prepared previously.[4] Compound IV presumably was formed by *bis* rearrangement of that form of the dioxime in which the azulene ring was *anti* to the hydroxyl of both oxime functions. V must arise from hydrolysis during work-up, possibly of a chloroimine group formed by reaction of the oxime with phosphorus pentachloride or, alternatively, unreacted oxime might have been hydrolyzed during the several chromatographic processes which were performed. As will be shown later, the latter explanation is probably not the correct one. The results do not permit definite deductions regarding the configuration of the second oxime group in the precursor to V.



III IV V

The above observations led to a more thorough study of the reaction. When a catalytic amount of sulfuric acid was added to a solution of III in ethanol and dichloromethane, the only product was unchanged starting material. Repetition of this reaction in ethanol alone again gave mostly starting material plus small amounts of two products, one of which was identified as V.[5] Thus essentially no rearrangement or hydrolysis (the reactions were quenched with water) occurred with sulfuric acid.

When a similar reaction was carried out using acetic anhydride and sodium acetate a diverse mixture of products was formed. Since the rearrangement presumably proceeds *via* the acetylated oxime under these conditions, it was decided to try to isolate the intermediate diacetate of III. When the reaction was repeated and stopped after two minutes, two main products (one dark blue, the other pale violet) were obtained, both of which analyzed as the expected diacetate. As will be shown later, these compounds are probably the isomeric structures VI (68.5%) and VII (15.5%). In no run was any product corresponding to the third possible geometric isomer observed. Also it was found that VII would not isomerize to VI under the conditions of the acetylation.



III VI VII

The rearrangement of the two diacetates was investigated next. When a mixture of VI and VII as obtained from the acetylation of III was heated with the dilute acetic acid, IV (5.5%) and V (16%) were again the products formed. When a mixture of the diacetates was chromatographed over basic

(1) Taken in part from the Ph.D. Thesis of Charles G. Fritz.

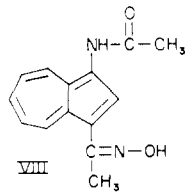
(2) Supported in part by contract DA-04-4200-ORD-235 with the Office of Ordnance Research, U. S. Army, and by the Agnes H. Anderson Research Fund.

(3) A. G. Anderson, J. A. Nelson and J. J. Tazuma, THIS JOURNAL, **75**, 4987 (1953).

(4) A. G. Anderson, R. Scotoni, E. J. Cowles and C. G. Fritz, *J. Org. Chem.*, **22**, 1193 (1957).

(5) The other product from the sulfuric acid-catalyzed reaction was not obtained from any other rearrangement nor characterized. It is possibly 1,3-diacetylazulene monoxime.

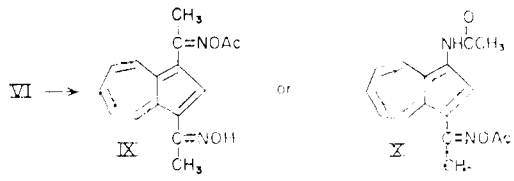
alumina, IV (*ca.* 30%) was again obtained along with either V (*ca.* 30%) or VIII (11%), the oxime precursor of V. When V was formed there was also recovered some unrearranged diacetate VI. The identity of VIII was shown by the preparation of this new product in 93% yield from V.



VIII

A series of experiments was next carried out on the rearrangement of pure VI. When VI was warmed with a sodium acetate buffered ethanol solution, the same two compounds were formed; 44% of IV but only trace amounts of V. The proportions of sodium acetate, acetic anhydride and acetic acid were then varied in a regular manner for three runs such that one was basic, one approximately neutral and one relatively acidic. It was observed that the relative amounts of IV and V formed varied from 0% IV and 69.8% V with excess sodium acetate to 46.5% IV and 21.8% V with excess acetic acid. Also, in the basic and neutral runs a third product (VIII) was formed in 30 and 2% yields, respectively. The total yields for the three runs were 99.8, 95 and 68.3%.

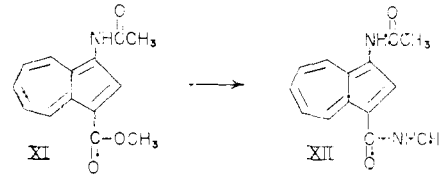
On the basis of the above results certain statements may be made. The hydrolysis of the oxime acetate group to the free oxime occurs readily and the subsequent hydrolysis of the oxime to the ketone is, as expected, more nearly complete under the more acidic conditions. Apparently, also, the free oxime has a lesser tendency than the oxime acetate to go to the ionic species which rearranges. The lower total yield from the more acidic reaction conditions would seem to indicate that either the observed rearrangement products are less stable in acid or that other unstable products are formed. It was determined that IV did indeed undergo hydrolysis readily under acidic conditions. None of the expected diamine could be isolated, however, so this compound, like 1-aminoazulene, is apparently quite unstable. It may be argued that the two groups do not rearrange simultaneously to form IV and, also, that the first rearrangement process would be sufficiently slow (the intact oxime acetate group present is electron withdrawing, as evidenced by its causing a hypsochromic shift of 12 mμ in the visible spectrum, and might have some effect on the reaction) to permit the occurrence of a parallel reaction to form IX, either by attack of the positive nitrogen by the solvent or by base-catalyzed hydrolysis of the acetate ester.



Either process would take place more readily in the more basic solutions. IX could then rearrange to give VIII and this, on hydrolysis, would give V. Alternatively IX could undergo further attack by the solvent to give III. This step might be retarded, and the rearrangement aided, by the influence of the oxime group present which causes a bathochromic shift (+13 mμ) and thus is apparently electron donating. This would account for the formation of V and VIII and of no dioxime III or hydrolysis products of III.[6]

When the first rearrangement precedes hydrolysis, X is formed and this may now further rearrange to IV, a step which would possibly be favored by the presence of the acetamido group, or undergo hydrolysis to give VIII and V. As the actual sequence of reactions leading from VI to the various products was not determined (this would be extremely difficult if possible at all), the above comments are, for the most part, quite tentative conclusions. It should be noted that the structures of the three products formed are consistent with the structure formulated for VI.

The rearrangement of pure VII was now examined. It had been observed that some reaction took place when the purification of this compound was attempted by chromatography on acid-washed alumina. Repetition of this procedure with separation and isolation of the products showed that V and VIII were being formed by rearrangement on the column.[7] Treatment of VII with a buffered ethanolic solution of sodium acetate and acetic acid gave, surprisingly, the same three products, IV (5.4%), V (28.4%) and VIII (18.2%), that had been obtained from VI. It will be noted that the total yield (*ca.* 52%) was considerably lower than those from the rearrangement of VI, that none of the rearrangement product having an N-methylcarboxamido group (XII) was found, and that IV would not be formed directly from the structure given for VII. No reason was found for the lower total yield of products. The absence of XII in the products may mean that the oxime acetate configuration having the methyl and acetate groups *anti* underwent hydrolysis at a rate exceeding that of rearrangement. An alternative explanation that the N-methylcarboxamido group was not stable under the conditions of the reaction was shown not to be the case when XII was prepared from XI[4] by treatment of the latter with methylamine and was found to be stable.



XI XII

The formation of the small amount of IV would be accounted for if VIII were contaminated with VI. This possibility seemed likely since the two isomers were separated by fractional crystallization and, further, since in some runs of the rearrangement of VII no IV was obtained. To substantiate this postulation the purity of VII was

(6) In a few runs trace amounts of 1,3-diacetylazulene were isolated.

(7) In contrast, VI could be chromatographed repeatedly on acid-washed alumina without appreciable rearrangement or decomposition.

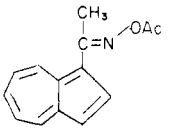
TABLE I

ABSORPTION SPECTRA (mμ AND CM.$^{-1}$) OF 1,3-DISUBSTITUTED AZULENES[a]

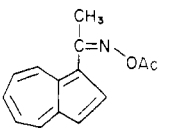
Groups	λ_{max} Calcd.	λ_{max} Obsd.	% dev.[b]	$1/\lambda_{max}$ Calcd.	$1/\lambda_{max}$ Obsd.	% dev.[b]
$CH_3C(=NOH)$, $CH_3C(=NOH)$[c]	606	610	0.7	16500	16400	0.6
$CH_3C(=NOH)$, $-NHCCH_3$ (O)	633	630	.5	15570	15870	1.9
$CH_3C(=NOH)$, $-COCH_3$ (O)	556	552	.7	18080	18120	0.2
$-C(=O)-NHCH_3$, $-CNHCH_3$[d] (O)	526	525	.2	18960	19050	.5
$-C(=O)-NHCH_3$, $-NHCCH_3$ (O)	593	590	.5	16800	16950	.9
$-C(=O)-NHCH_3$, $-CCH_3$ (O)	510	510	.0	19620	19610	.1
$-C(=O)-NHCH_3$, $CH_3C(=NOH)$	566	570	.5	17730	17540	1.1

[a] All spectra were taken in alcohol. [b] % deviation = difference + λ_{max} (obsd.) or $1/\lambda_{max}$ (obsd.) × 100 to the nearest 0.1. [c] Average shift is +14 mμ or −400 cm.$^{-1}$. [d] Average shift is −26 mμ or +830 cm.$^{-1}$.

examined more closely. The color (VII was pale violet and VI dark blue), melting point (which was sharp) and ratio of the peak heights in the infrared were all found to be constant for the samples of VII which gave IV and those which did not. This indicated that VII was a pure compound and that the two peaks at 5.7 and 5.85 μ resulted from the presence of two slightly different carbonyl groups rather than from the presence of IV (which showed a single peak at 5.7 μ) as an impurity. Strong evidence for the correctness of this conclusion was provided by the preparation of the acetate of the oxime of 1-acetylazulene. This compound should exist as a mixture of the *syn* (XIII) and *anti* (XIV) forms and, if the two carbonyls are different as postulated, show absorption at both 5.7 and 5.85 μ. This was found to be the case. Indeed, no evidence for the presence of VI in VII was obtained.



XIII

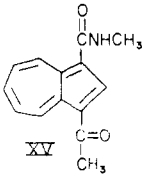


XIV

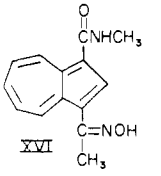
The partial isomerization of VII to VI would afford a second way in which IV could be formed. This isomerization did not take place on prolonged standing of VII either in the solid or liquid phase or with an inert solvent. Further, no conversion to VI was effected by refluxing VII in a sodium acetate buffered acetic anhydride solution (the conditions of acetylation). In spite of these results, isomerization under the rearrangement reaction conditions is not precluded and, at this point, seems the more likely explanation.

The assignment of the structures shown for VI and VII is reasonable with respect to the results of the rearrangement reactions and is supported by consideration of the infrared spectra and molecular models. The carbonyl absorption data discussed above are consistent with the configurations presented. Further, in the models wherein the acetate group is *anti* to the azulene ring the entire oxime acetate substituent is free to rotate around the bond joining it to the ring and at no position is the ester group in close proximity with the 7-membered ring. For the other configuration (acetate group *syn* to the azulene ring), however, free rotation cannot occur and the carbonyl group may get so close to the 7-membered ring that interaction of the negative end of the carbon–oxygen dipole with the positive end of the azulene dipole would occur. This would account for the observed displacement of the carbonyl absorption from 5.7 to 5.85 μ. Finally, the molecular models show that the isomer in which both acetate groups are *syn* to the ring is sterically considerably less favored than either of the others.

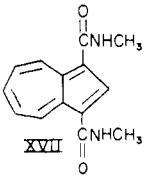
When the rearrangement products were first obtained we had not synthesized all of the compounds obtained and, indeed, anticipated that some would involve the N-methylacetamido group. Accordingly three other possible products of this type were prepared. The first (XV) was obtained (68%) from methyl 3-acetylazuloate[4] by reaction with methylamine, the second (XVI) from the same intermediate but *via* the oxime and the third (XVII) by corresponding aminolysis of dimethyl 1,3-azulenedicarboxylate.[4]



XV



XVI



XVII

A number of the new compounds prepared have new substituent groups and it was of interest to continue with these the study of the approximate

additivity of the spectral shifts in the visible region for groups on the 1- and 3-positions.[4,8] Average values for the shifts for the acetyl oxime and N-methylcarboxamido groups were determined using the previously calculated values for the acetamido, carboethoxy and acetyl groups[4] when these were involved. The agreement between the calculated maxima thus obtained and the observed values (Table I) is seen to be, as found previously with other groups, quite good.

Experimental[9,10]

1,3-Diacetylazulene Dioxime (III).—A solution of 300 mg. (4.35 mmoles) of hydroxylamine hydrochloride and 350 mg. of sodium acetate in 3 ml. of water was added to 42.5 mg. (0.2 mmole) of 1,3-diacetylazulene in 12 ml. of warm ethanol. The mixture was heated on a steam-bath for 3.5 hr. and during this period the color changed from red to blue. Warm water (20 ml.) was then added and the green crystals which separated (overnight) were collected and dried. They amounted to 42 mg. (87%) and did not melt at 250°. Ultraviolet absorption maxima were observed ($m\mu$, D_{max}) at 262, 2.78; 187, 2184; 310, 184; and 386, 0.59. The visible spectrum showed a single maximum at 610 $m\mu$.

Anal. Calcd. for $C_{14}H_{14}N_2O_2$: C, 69.36; H, 5.83. Found: C, 69.17; H, 6.00.

Rearrangement of 1,3-Diacetylazulene Dioxime. A. With Phosphorus Pentachloride.—To a solution of 22.9 mg. (0.095 mmole) of the above dioxime in 30 ml. of absolute ether was added 0.3 g. (1.4 mmoles) of phosphorus pentachloride and the mixture shaken until a brown precipitate separated and the solution became a brown-green color. The mixture was poured into 50 ml. of water and the whole extracted with ether. After neutralization of the aqueous layer with a potassium carbonate solution saturated with sodium sulfate, it was again extracted with ether. The combined ether extracts were dried over sodium sulfate and the solvent was removed. Chromatography of the residue on alumina with dichloromethane gave two eluate fractions, red and light green. From the first was isolated 1.1 mg. of 1,3-diacetylazulene and from the second 2.4 mg. of 1-acetamido-3-acetylazulene (V). Elution with chloroform yielded an additional 3 mg. of V from a blue-green eluate fraction (total yield of V, 3.4 mg., 25.1%) and elution with acetone gave a blue fraction from which was obtained 4.8 mg. (21%) of 1,3-diacetamidoazulene (IV). The identity of the products was determined by comparison of melting points and absorption spectra (infrared for IV and V) with authentic samples.[3,4]

B. With Sulfuric Acid.—To a mixture of 37.5 mg. of the above dioxime and 30 ml. of ethanol was added with mixing 15 drops of concentrated sulfuric acid. The solution became blue-green, then green with a blue fluorescence and, after 2 hr., showed a red-violet fluorescence. The mixture was poured into 100 ml. of water and extracted with ether. Concentration of the ether solution and chromatography of the concentrate on alumina with dichloromethane gave mostly unreacted dioxime plus *ca.* 2 mg. of V, m.p. 200°, and *ca.* 3 mg. of an unidentified product as yellow needles.

1,3-Diacetylazulene Dioxime Diacetate (VI and VII).—A solution of 100 mg. (0.413 mmole) of 1,3-diacetylazulene dioxime and 1 g. of sodium acetate in 5 ml. of acetic anhydride was heated at the boiling point for 2 min. and then cooled. It was then poured into a mixture of crushed ice and 3 g. of sodium bicarbonate and the whole stirred for 20 min. The dichloromethane extract of the mixture was washed with water and the solvent removed. The solid residue was extracted with ether, the extracts evaporated to dryness and the residue again extracted with ether. The final ether solution yielded 17.5 mg. (15.5%) of diacetate VII as pale violet needles, m.p. 119–120° dec. This material exhibited absorption maxima ($m\mu$, D_{max}) at 236, 1.10; 300, 1.13; 374, 0.28; and a single peak at 571 $m\mu$.

Anal. Calcd. for $C_{18}H_{18}N_2O_4$: C, 66.24; H, 5.56. Found: C, 66.02; H, 5.84.

The ether-insoluble solid from the above procedure was triturated with dichloromethane and removal of the solvent from the organic solution afforded 72 mg. (68%) of diacetate VI as dark blue crystals, m.p. 160–161° dec. Absorption maxima were observed ($m\mu$, D_{max}) at 247, 1.27; 298, 2.37; 384, 0.40; and a single peak at 561 $m\mu$.

Anal. Calcd. for $C_{18}H_{18}N_2O_4$: C, 66.24; H, 5.56. Found: C, 66.03; H, 5.65.

1-Acetamido-3-acetylazulene Oxime (VIII).—A solution of 10.5 mg. (0.047 mmole) of 1-acetamido-3-acetylazulene (V),[4] 50 mg. (0.77 mmole) of hydroxylamine hydrochloride and 200 mg. of sodium acetate in 3 ml. of water and 5 ml. of ethanol was heated on a steam-bath for 12 hr. It was then added to 200 ml. of water and extracted four times with ether. The ether extracts were concentrated and the residue chromatographed on alumina. Elution with ethyl acetate gave a trace of starting material and 10.4 mg. (92.8%) of product as green needles, m.p. 219–220°. Ultraviolet absorption maxima ($m\mu$, D_{max}) were found at 247, 1.26; 289, 1.35; 302, 1.30, and 382, 0.39. The visible spectrum had a maximum at 630 $m\mu$.

Anal. Calcd. for $C_{14}H_{14}N_2O_2$: C, 69.36; H, 5.83. Found: C, 69.40; H, 6.02.

1-N-Methylcarboxamido-3-acetamidoazulene (XII).—A solution of 25 mg. (0.1 mmole) of methyl 3-acetamidoazuloate (XI)[4] in 10 ml. of methanol was combined with 15 ml. of 40% aqueous methylamine and the mixture allowed to stand for two weeks. During this time the color of the solution changed gradually from a light to a dark blue. After evaporation of the solvent and excess methylamine, the residue was chromatographed on acid-washed alumina. Elution with chloroform removed a small amount of starting material and acetone eluted the product. Recrystallization of the latter from ligroin and acetone gave 18 mg. (72%) of dark green needles, m.p. 213–214°. Ultraviolet absorption maxima ($m\mu$, D_{max}) were observed at 242, 0.90; 300, 1.42; and 375, 0.29. The maximum in the visible region was at 590 $m\mu$.

Anal. Calcd. for $C_{14}H_{14}N_2O_2$: C, 69.36; H, 5.83. Found: C, 69.44; H, 5.91.

1-Acetylazulene Oxime Acetate (XIII and XIV).—A solution of 37 mg. (0.2 mmole) of 1-acetylazulene oxime and 0.5 g. of sodium acetate in 3 ml. of acetic anhydride was heated at the boiling point for 3 min., then added to a mixture of crushed ice and 3 g. of sodium bicarbonate and the whole stirred for 20 min. The dichloromethane extract of this mixture was evaporated just to dryness and the residue recrystallized to give 35.6 mg. (79%) of blue needles, m.p. 105°. Absorption maxima ($m\mu$, D_{max}) in the ultraviolet were found at 234, 0.98; 277, 1.95; 282, 1.84; 287, 1.56; 341, 0.27; and 354, 0.21. The maximum in the visible region was at 578 $m\mu$.

Anal. Calcd. for $C_{14}H_{13}NO_2$: C, 73.99; H, 5.77. Found: C, 73.91; H, 5.76.

1-N-Methylcarboxamido-3-acetylazulene (XV).—A solution of 6.6 mg. (0.029 mmole) of methyl 3-acetylazuloate[4] in 4 ml. of 50% methanolic methylamine was allowed to stand for 3 days. The solvent was then removed and the residue chromatographed on alumina. Elution with dichloromethane removed a small amount of starting material and a 1:1 mixture of dichloromethane and chloroform removed the product. From the latter fraction was obtained 4.4 mg. (67.7%) as red needles, m.p. 172°. Absorption maxima were observed ($m\mu$, D_{max}) in the ultraviolet at 236, 1.92; 281, 2.10; 300, 1.75; 308, 1.83; 370, 0.65; and 381, 0.67. The maximum in the visible region was at 510 $m\mu$.

Anal. Calcd. for $C_{14}H_{13}NO_2$: C, 73.99; H, 5.77. Found: C, 74.02; H, 6.01.

Methyl 3-Acetylazuloate Oxime.—A solution of 4.9 mg. (0.0215 mmole) of methyl 3-acetylazuloate,[4] 20 mg. (0.288 mmole) of hydroxylamine hydrochloride and 60 mg. of sodium acetate in 3 ml. of ethanol was heated on a steam-bath for 5 hr. The reaction mixture was then added to 150 ml. of water and the whole extracted with ether. The

(8) E. J. Cowles, THIS JOURNAL, **79**, 1093 (1957).

(9) Melting points were taken on a calibrated Fisher–Johns apparatus and are uncorrected. Ultraviolet and visible spectra were taken in ethanol on a Cary model 115 recording spectrophotometer unless otherwise indicated.

(10) Microanalyses were performed by B. Nist and C. H. Ludwig.

solvent was removed and the residue chromatographed on Florisil. Chloroform eluted the product which was isolated (5 mg., 95.8%) as violet needles, m.p. 186°. Ultraviolet absorption maxima were found ($m\mu$, D_{max}) at 241, 1.64; 279, 1.78; 306, 1.55; and 379, 0.48. The visible spectrum showed a single peak at 552 $m\mu$.

Anal. Calcd. for $C_{14}H_{13}NO_3$: C, 69.11; H, 5.39. Found: C, 69.22; H, 5.35.

1-N-Methylcarboxamido-3-acetylazulene Oxime (XVI).—The above methyl 3-acetylazuloate oxime (19.7 mg., 0.081 mmole) was dissolved in 4 ml. of a 1:1 solution of 40% aqueous methylamine and 50% alcoholic methylamine and the reaction mixture allowed to stand for 3 days. The solvent was then evaporated (air-stream) and the residue chromatographed on alumina. Chloroform eluted 9 mg. of starting material. The product (9.7 mg., 49.5%) was then removed from the column with acetone and obtained as pale violet crystals, m.p. 181° dec. The substance exhibited ultraviolet absorption maxima ($m\mu$, D_{max}) at 242, 1.55; 280, 1.60; 303, 1.42; and 377, 0.35. The maximum in the visible region was observed at 570 $m\mu$.

Anal. Calcd. for $C_{14}H_{14}N_2O_2$: C, 69.36; H, 5.83. Found: C, 69.48; H, 6.06.

1,3-Di-(N-methylcarboxamido)-azulene (XVII).—A solution of 25.5 mg. (0.1045 mmole) of dimethyl 1,3-azulenedicarboxylate[4] in 4 ml. of 40% aqueous methylamine and 4 ml. of 50% methanolic methylamine was allowed to stand for 3 days and during this time the solution darkened considerably. Removal of the liquids (air-stream) left a residue which was chromatographed on alumina. Elution with dichloromethane gave 2.9 mg. of recovered diester. Acetone gave two darker red bands. The first yielded 2 mg. of a product which was not characterized but was thought to be methyl 3-N-methylcarboxamidoazuloate. The second, a dark violet-red in color and containing the main product, yielded 16.2 mg. (63.8%) of violet needles, m.p. 227–228° dec. Ultraviolet absorption maxima ($m\mu$, D_{max}) were observed at 233, 1.39; 270, 1.20; 298, 1.76; 340, 0.34; and 366, 0.53. The visible spectrum showed a single peak at 525 $m\mu$.

Anal. Calcd. for $C_{14}H_{14}N_2O_2$: C, 69.36; H, 5.83. Found: C, 69.55; H, 5.99.

Rearrangement of Mixed 1,3-Diacetylazulene Dioxime Diacetates (VI and VII). A.—A solution of 180 mg. (0.75 mmole) of the diacetylazulene dioxime and 500 mg. of sodium acetate in 7 ml. of acetic anhydride was refluxed for 2 hr. during which time the color changed to lavender. Water (100 ml.) was then added and the mixture heated on a steam-bath for 2 hr. During this period the color gradually changed to a blue-green. After saturation with sodium bicarbonate and sodium sulfate the mixture was extracted with ether, the ethereal extracts dried over sodium sulfate and the solvent removed (air-stream). The residue was separated into two fractions by chromatography (several times) on alumina with dichloromethane. From the two eluate fractions were obtained 9.3 mg. (5.5%) of 1,3-diacetamidoazulene (IV) as green needles, m.p. 245–250°,[4] and 21.5 mg. (16%) of 1-acetamido-3-acetylazulene (V) as green needles, m.p. 200°.[4] It was noted that some transformation of the products into an unidentified yellow compound occurred on the chromatograph column.

B.—A solution of 180 mg. (0.75 mmole) of the diacetylazulene dioxime in 4 ml. of acetic anhydride was added to 1.5 g. of sodium acetate. After 10 min. the mixture, which had changed rapidly to violet-blue in color, was heated to boiling for *ca.* 20 sec. and then allowed to stand overnight. Crushed ice was added, the mixture extracted with dichloromethane, and the combined extracts washed with cold aqueous sodium bicarbonate. The solvent was evaporated from the dried (sodium sulfate) organic solution with final heating (steam-bath) under vacuum to remove acetic anhydride present. The residue was extracted with ether and the extract solution chromatographed on alumina. A 2:3 dichloromethane–hexane solvent was added and a green zone developed. Successive elution with dichloromethane, ether and ethyl acetate removed only traces of material but caused formation of green crystals in the column. The green product was eluted with methanol and rechromatographed on acid-washed alumina. A mixture of ethyl acetate and methanol (96:4) removed one product (IV) which was isolated as green needles (50 mg., 27.8%), m.p. 252–257°.[4] A second fraction was eluted with a 9:1 ethyl acetate–methanol solvent and yielded 20 mg. (11%) of VIII as green needles, m.p. 218–219°, which showed the same infrared spectrum as an authentic sample.

The products obtained from the above procedure varied somewhat from run to run. For example, one run starting with 50 mg. (0.21 mmole) of the dioxime yielded *ca.* 10 mg. (32%) of unrearranged dioxime diacetate (VI), m.p. 155–160°, and *ca.* 15 mg. (30%) of V, m.p. 200°. The only evidence for the formation of any VIII was a small impure fraction which appeared to melt with decomposition at approximately 220° and could not be purified further.

Rearrangement of 1,3-Diacetyldioxime Diacetate (VI). A.—A solution prepared by dissolving 18.2 mg. (0.08 mmole) of the dioxime diacetate, 1 g. of sodium acetate and 0.1 ml. (1.0 mmole) of acetic anhydride in 5 ml. of ethanol was heated under reflux on a steam-bath for 1 hr., then cooled and added to 100 ml. of water. The aqueous solution was extracted with ether until nearly colorless and the solvent removed (air-stream) from the combined extracts. The residue was chromatographed on acid-washed alumina with chloroform and then acetone. The first eluate fraction contained 8.8 mg. (69.8%) of 1-acetamido-3-acetylazulene (V), identified by its ultraviolet, visible and infrared spectra. From the second fraction was obtained 3.8 mg. (30%) of 1-acetamido-3-acetylazulene oxime (VIII) as shown by comparison of the melting point and absorption spectra with those of an authentic sample.

B.—A solution of 41.2 mg. (0.182 mmole) of the dioxime diacetate, 70 mg. of sodium acetate and 0.25 ml. (2.5 mmoles) of acetic acid in 0.1 ml. of water and 6 ml. of ethanol was refluxed on a steam-bath until the color changed from a violet-blue to a blue-green (1.5 hr.). After neutralization with aqueous sodium bicarbonate, the mixture was extracted with ether until colorless and the combined extracts evaporated (air-stream) to dryness. The residue was chromatographed on acid-washed alumina. Dichloromethane eluted a small red band containing 0.5 mg. of 1,3-diacetylazulene. Elution with chloroform then removed a bluish-green fraction which yielded 18.3 mg. (64.2%) of 1-acetamido-3-acetylazulene (V). Acetone eluted a fraction giving 0.6 mg. (2%) of 1-acetamido-3-acetylazulene oxime (VIII) and then a fraction from which was obtained 8.7 mg. (28.6%) of 1,3-diacetamidoazulene (IV). The products were identified by mixed melting points and/or comparison of their ultraviolet, visible and infrared absorption spectra with those of authentic samples.

C.—A solution of 48.6 mg. (0.21 mmole) of the dioxime diacetate and 0.25 ml. (0.25 mmole) of acetic acid in 5 ml. of ethanol was refluxed on a steam-bath until the color changed from violet-blue to blue-green (5 hr.). The reaction mixture was worked up as described in **B** above. It was necessary to chromatograph the crude product several times in order to obtain a good separation. The last chromatogram was developed first with a 7:3 mixture of dichloromethane and chloroform which eluted 7.3 mg. (21.8%) of 1-acetamido-3-acetylazulene (V). Acetone then removed 16.6 mg. (46.5%) of 1,3-diacetamidoazulene (IV). The products were identical (melting point, ultraviolet, visible and infrared spectra) with those obtained as described above.

Rearrangement of 1,3-Diacetyldioxime Diacetate (VII). A.—A solution of 57 mg. (0.25 mmole) of the dioxime diacetate, 0.5 g. of sodium acetate and 0.25 ml. (0.25 mmole) of acetic acid in 7 ml. of ethanol was refluxed on a steam-bath for 1.5 hr. After the addition of 150 ml. of water the mixture was extracted with ether until nearly colorless. Evaporation (air-stream) of the solvent from the combined extracts left a residue which was chromatographed on alumina. Elution with dichloromethane developed a small violet band which turned green as it moved down the column. This was probably unchanged VII undergoing rearrangement on the column (see B below). This fraction was not collected separately, but rather the column was stripped with methanol, the eluate concentrated and the residue rechromatographed. Two main fractions were now obtained, one with dichloromethane and then the other with acetone. Further chromatography of the first fraction (three times) separated it into two components from which were obtained 11.2 mg. (28.4%) of 1-acetamido-3-acetylazulene (V) and 7.7 mg. (18.2%) of 1-acetamido-3-acetylazulene oxime (VIII). The second fraction initially eluted with acetone yielded 2.7 mg. (5.4%) of IV. The identity of the products was shown by comparison of their melting points (except

for VIII) and ultraviolet, visible and infrared (except for IV) spectra with those of authentic samples.

B.—A small quantity of the dioxime diacetate VII was applied to a carefully prepared column of acid-washed alumina with dichloromethane. The violet layer which developed slowly turned green as it moved down the column. When none of the violet color remained, the column was washed with acetone and ethanol, the eluate evaporated and the residue rechromatographed. Chloroform eluted a fraction containing 14.3 mg. of 1-acetamido-3-acetylazulene (V), and acetone containing a little ethanol removed a second fraction which yielded 10.4 mg. of 1-acetamido-3-acetylazulene oxime (VIII). The products were identified as in A above. A relatively large amount of brown material remained on the column.

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[CONTRIBUTION FROM THE DEPARTMENT OF CHEMISTRY, WAYNE STATE UNIVERSITY]

Cyclic Dienes. XXI. Diels–Alder Adducts and Cyclodecane Derivatives from 1,2-Dimethylenecyclohexane[1,2]

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The reaction of 1,2-dimethylenecyclohexane with a wide variety of dienophiles produced a series of $\Delta^{9(10)}$-octalin derivatives. These Diels–Alder adducts were transformed into several other substituted $\Delta^{9(10)}$-octalins by conventional reactions. Ozonization of these octalin derivatives produced directly a series of highly substituted cyclodecane derivatives, which might serve as starting materials for the synthesis of cyclodecapentaene. The diketones containing electron-withdrawing groups were extremely susceptible to intramolecular condensation, but the other derivatives were somewhat more stable.

Cyclic dienes, such as 1,2-dimethylenecyclohexane (I),[5] have attracted interest because they produce multicyclic adducts through the Diels–Alder reaction. Many uses of these interesting dienes and their Diels–Alder adducts already have been reported. For example, 1,2-dimethylenecyclohexane (I) was polymerized to produce the first synthetic all-*cis* diene polymer related in structure to natural rubber.[6] The adduct from benzoquinone and the diene I was shown to be an excellent starting material for the synthesis of pentacene,[7] and the adduct of the diene I and maleic anhydride was shown to be an excellent starting material for the synthesis of 2,3-dimethylenedecalin.[8] Related materials also have been prepared from the series of substituted dimethylenecyclohexanes.[9,10]

Since the Diels–Alder adducts are derivatives of $\Delta^{9(10)}$-octalin, it appeared that these bicyclic compounds could be used as starting materials for the preparation of cyclodecane derivatives. Nametkin and Glagolew[11] and Hückel and Blohm[12] developed a procedure for the synthesis of cyclodecane derivatives through the ozonization of $\Delta^{9(10)}$-octalin. Improved variations of this procedure have been reported more recently.[13–15] Since normal ring closures give poor yields for ten-membered carbocyclic rings,[16] several alternative processes have been developed. The most attractive methods for the preparation of cyclodecane derivatives include the rearrangement of the benzoate of decalin hydroperoxide[17] and the acyloin condensation of diethyl sebacate.[18,19] However, none of these methods is well adapted for the preparation of highly substituted cyclodecane derivatives. These derivatives are of interest as possible starting materials for the preparation of cyclodecapentaene, but the introduction of five double bonds into a ring with only two functional groups would be quite difficult. It seemed reasonable that, since the synthesis of 1,2-dimethylenecyclohexane (I) can be modified to introduce additional functional groups,[20,21] the synthesis of highly substituted cyclodecane derivatives from their intermediate Diels–Alder adducts would be practical. For this reason the preparation of a series of Diels–Alder adducts of 1,2-dimethylenecyclohexane (I) was undertaken and the conversion of these adducts to cyclodecane derivatives was studied.

When nitroethylene, prepared by the pyrolysis of β-nitroethyl acetate, was allowed to react with 1,2-dimethylenecyclohexane (I), an 85% yield of the Diels–Alder adduct, 2-nitro-$\Delta^{9(10)}$-octalin (IIa), was obtained. Since mechanical difficulties were encountered in the ozonization of IIa, several variations were tried. The most satisfactory procedure was to bubble the ozone through a gas-washing bottle containing a solution of IIa in 75% acetic acid at 0°. Under these conditions, the ozone was absorbed slowly, the ozonide was hydrolyzed and the resulting 3-nitro-1,6-cyclodecadione (IIIa) pre-

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