Pyrazol-3-ones as *cis*-Azodienophiles[1,2]

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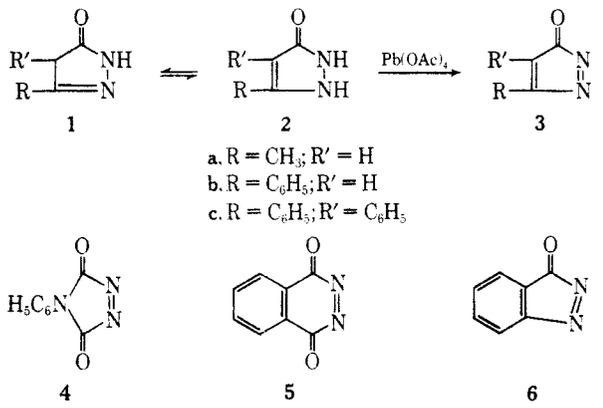
The oxidation of 3-methyl-2-pyrazolin-5-one (**1a**), 3-phenyl-2-pyrazolin-5-one (**1b**), and 3,4-diphenyl-2-pyrazolin-5-one (**1c**) with lead tetraacetate in the presence of dienes furnished Diels–Alder adducts. Adduct formation demonstrated the intermediacy of substituted pyrazol-3-one ring systems (**3**), which are diaza analogs of cyclopentadienone. The reactivity of 5-methylpyrazol-3-one (**3a**) was determined by observing its reaction with a series of dienes. Adducts were obtained with isoprene, 2,3-dimethyl-1,3-butadiene, cyclopentadiene, cyclohexadiene, α-phellandrene, and 1,4-diphenylbutadiene. The adducts are derivatives of the 1,4-dihydropyrazolo-[1,2-*a*]pyridazin-6-one ring system. Homoconjugate addition was observed in the reaction between **3a** and cycloheptatriene which gave 2,3-cyclopropa[*d*]-1,4-etheno-8-methyl-1,2,3,4-tetrahydropyrazolo[1,2-*a*]pyridazin-6-one (**13**). The oxidation of 3,4-diphenylpyrazolidin-5-one with lead tetraacetate presumably gave 3,4-diphenyl-1-pyrazolin-5-one which decomposed to *trans*-stilbene before tautomerization or adduction to cyclopentadiene could occur.

The use of azodienophiles such as ethyl azodicarboxylate with acyclic and cyclic dienes is an efficient method of obtaining pyridazines and diazabicyclic systems.[4] *cis*-Azodienophiles have recently been shown to be generally more reactive than *trans*-azodienophiles and to allow entry into unusual heterocyclic systems.[4–8] It was the purpose of this investigation to develop new *cis*-azodienophiles in order to extend the synthetic utility of azo systems.

The unstable pyrazol-3-one ring system (**3**) has been formed *in situ* through the oxidation of substituted pyrazolin-3-ones **1** and **2** with lead tetraacetate and has been trapped in the presence of dienes through the Diels–Alder reaction (Scheme I). Pyrazol-3-one is

SCHEME I



both a diaza analog of cyclopentadienone and a *cis*-acylazo compound and it thus would be expected to be a potent though unstable azodienophile. The reactivity of azodienophiles is increased if the azo linkage is electron deficient and sterically unhindered. It may then be expected that the pyrazol-3-one system may then be placed between 4-phenyl-1,2,4-triazoline-3,5-dione (**4**)[5,6] and phthalazine-1,4-dione[7–9] (**5**) which are more reactive and ethyl azodicarboxylate which is less reactive in a scale of dienophilic[10–13] reactivity on the basis of the chemical structure of **3**.

The dienophilic character of the ring system has been indicated previously by trapping the benzo derivative **6** with butadiene and cyclopentadiene.[14] In another case the base-catalyzed decomposition of 3,4-diphenyl-4-chloropyrazolin-5-one has been found to give **3c** as an intermediate which has been trapped with cyclopentadiene and with butadiene.[15]

2-Pyrazolin-5-one (**1**) derivatives are oxidized exclusively to the azo compounds (**3**). The tautomeric structures (**2**) that are present in solution[16] are hydrazo moieties which are oxidized in this manner with lead tetraacetate.[6,8,14] No evidence was found for the presence of an azoacetate intermediate, 3-methyl-3-acetoxyl-1-pyrazolin-5-one, in the oxidation of **1a** as observed in the oxidation of unacylated hydrazones.[17,18] Initial investigations on the oxidation of **1a** with lead tetraacetate showed that the reaction was exothermic and gave rise to a highly colored transitory intermediate. Similar behavior of other *cis*-hydrazo compounds such as N-phenylurazole,[5,6] 1,2-dihydro-3,6-pyridazinedione,[8] and 3-indazolinone[14] on reaction with lead tetraacetate to give **4**, **5**, and **6**, respectively, indicated an analogous reaction was occurring. When the oxidation was carried out in the presence of a reactive diene no transitory color was observed and an adduct was formed in high yield indicating that the intermediate was being utilized as soon as it was formed.

In order to determine the reactivity of the ring system, 5-methylpyrazol-3-one (**3a**) was allowed to react with a series of dienes of different reactivities. Adducts were obtained with four reactive dienes, which include 1,4-diphenylbutadiene, 2,3-dimethylbutadiene, cyclopentadiene, and α-phellandrene, and with two less reactive dienes, cyclohexadiene and cycloheptatriene, which do not give Diels–Alder adducts with

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(2) Presented at the 154th National Meeting of the American Chemical Society, Chicago, Ill., Sept 1967, Abstract No. S-39.

(3) National Aeronautics and Space Administration Fellow, 1965–1967.

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(17) D. C. Iffland, L. Salisbury, and W. R. Schafer, *J. Am. Chem. Soc.*, **83**, 747 (1961).

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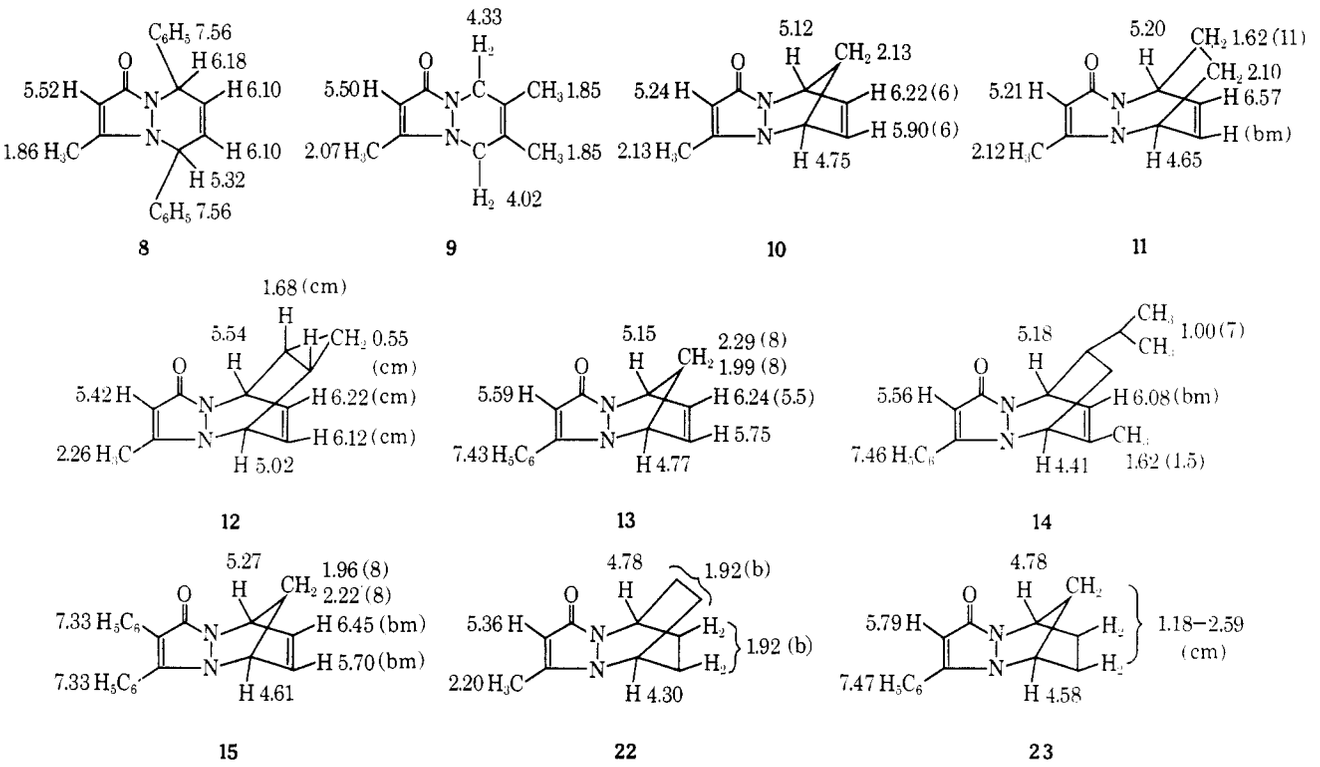
CHART I



ethyl azodicarboxylate.[13,19,20] The product obtained with isoprene did not exhibit properties of a normal adduct. No adduction was observed with anthracene, 1,3-cyclooctadiene, and bicycloheptadiene which have given adducts with certain other *cis*-azodienophiles.[6,9] No adduct was obtained with bicycloheptadiene; the diene reacted with lead tetraacetate to give 2-*exo*-7-*syn*-norbornane-2,4-diacetate,[21] thus consuming the lead tetraacetate before it oxidized the pyrazolin-5-one (**1a**). No reaction was observed with the very unreactive diene, *trans*-muconic acid, but 2,5-dimethyl-2,4-hexadiene with **1a** and lead tetraacetate gave 3,3,6-trimethyl-2-isobutenyl-2,3-dihydropyrazolo[2,3-*b*]-1,3-oxazole (**7**), a new ring system.

The reactions were generally carried out at −10° in methylene chloride solvent by the addition of lead tetraacetate to a suspension of the pyrazolin-5-ones and the diene. Oxidation usually required 3–4 hr. The higher melting point of the adducts of **3b** make purification easier and yields generally higher than the adducts of **3a**. The adducts formed are listed below in the order mentioned. The amount of material isolated on evaporation of the solvent was a useful guide to the relative amounts of adducts formed as it was independent of the methods of purification and reasonably pure as deduced from their infrared spectra.

The structure of the adducts **8**–**15** and of two reduction products **22** and **23** are given with their assigned pmr chemical shifts (Chart I). The pmr spectra showed broad peaks for the bridgehead and N-substituted methylenes. The peaks for the pyrazoline ring protons were sharp singlets. Where splitting was resolved the coupling constants are indicated by the numbers in parentheses (Hz). In all cases these are for doublets centered at the assigned frequency. Complex multiplets are indicated by cm, a broad multiplet by bm, and a broadened peak by b.

The infrared spectra of the adducts of **3a** show carbonyl absorption at 6.10 μ; the adducts of **3b** show carbonyl absorptions at 5.97 μ, peaks at 6.4 and 6.70 μ, and phenyl absorptions are at 13.2–13.4 and 14.2–14.3 μ.

The decomposition products obtained from the oxidation of **1a** or **1b** with lead tetraacetate in the absence of a diene have not been determined. The intermediates **3a** or **3c** decompose without evolution of a gas to give a dark solid which contains lead as either a salt or complex. An organic material may be freed from lead by treatment of an ethanol solution with H_2SO_4 or CO_2 and water. The orange organic materials so obtained decompose between 127 to 250° with melting and gas evolution. Several methods were tried to obtain a pure sample but none was successful.

It is evident that the pyrazol-3-one ring system is less reactive than previously investigated *cis*-azodienophiles. This is attributed to the fact that the azo linkage in **3** is not so electron poor as those in **4** and **5**. The degree of substitution in the pyrazoline ring does not appear to hinder the oxidation so that any 3,4-substituted pyrazolinone should react to give the pyrazol-3-one.

The compound **7** represents a unique reaction product for *cis*-azodienophiles although the reaction between 2,5-dimethyl-2,4-hexadiene and 4-phenylurazole on oxidation with lead tetraacetate has been found to give compound **16**[6] (Table I).

The structure of **7**, $C_{12}H_{18}N_2O$, is indicated by spectroscopic evidence. The model compound, 5-ethoxy-1,3-dimethylpyrazole (**17**),[16] has a strong peak at 1562 cm^{-1} in the infrared spectrum as well as several other peaks which correspond to the infrared spectrum of **7**. The ultraviolet spectrum of **17**[16] showed only end ab-

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(20) J. M. Cinnamon and K. Weiss, *ibid.*, **26**, 2644 (1961).
(21) K. Alder, F. H. Flock, and H. Wirtz, *Ber.*, **91**, 609 (1958).

TABLE I

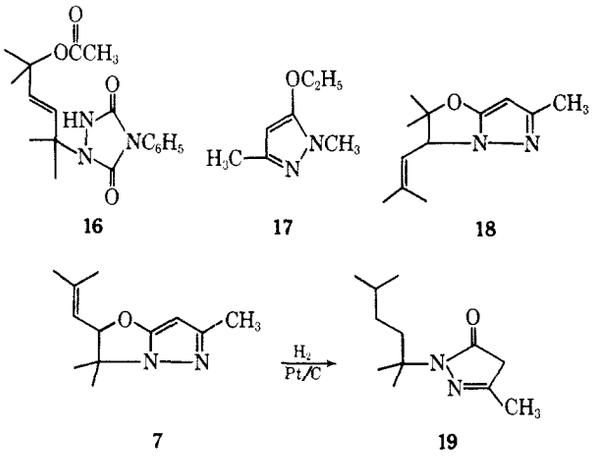
DIELS–ALDER ADDUCTS

Compd no.	Crude yield, %	Pure yield, %	Mp, °C	Ultraviolet spectra,[a] $\lambda_{max}^{95\%\ EtOH}$ mμ (ε)
8	96	78	136–137	259 (9640)
9	88	62	90–91	256 (9320)
10	53	40	109.5–110	282 (7730)
11	74	50	93–94	270 (6470)
12	49	10	90–91	276 (6230)
13	75	50	143–144	271 (13,200), 257[b] (15,000)
				305 sh (4500), 326 sh[b] (3780)
14	82	60	176–178	258 (11,300)
				300 sh (4000)
15	65	45	150–153	324 (8150)
				275 sh (7850)
				240 sh (15,100)
				217 sh (21,100)
22	92	80	61–62	254 (6590)
23	98	70	148–149	258 (18,300), 254[b] (15,600)
				310 (4000), 310[b] (3200)

[a] sh = shoulder. [b] Spectra taken in cyclohexane.

sorption in cyclohexane and λ_{max} 224 mμ (ε 7800) in 20 *N* sulfuric acid which agrees with the observed absorption λ_{max} 213 mμ (ε 2780) in cyclohexane and λ_{max} 224 mμ (ε 9250) in 20 *N* sulfuric acid for **7**. The pmr spectra of **7** showed five methyl peaks at 1.11, 1.50, 1.82, 1.86, and 2.13 ppm assigned to the ring methyls, the two side-chain vinyl methyls, and the pyrazole ring methyl group, respectively. The vinyl hydrogens gave peaks at 4.96 ppm and one peak at 5.37 ppm which overlapped the O-methine proton.

SCHEME II

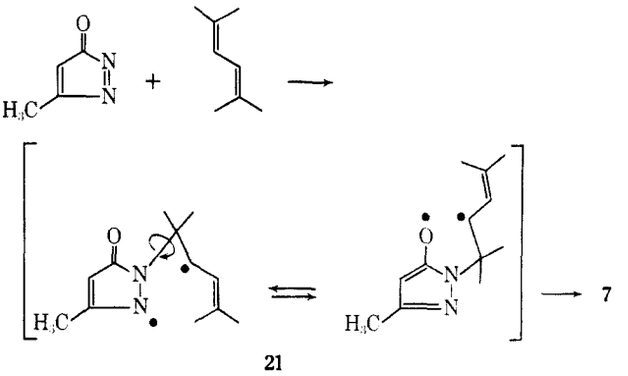


16 **17** **18**

7 **19**

Though this evidence is consistent with **7**, it may also be consistent with the isomeric structure **18**, (Scheme II). Catalytic hydrogenation of **7** over 5% platinum on charcoal led to the absorption of 2.3 equiv of hydrogen to give a compound (**19**) that has an infrared spectrum similar to **1a** and 1,3-dimethylpyrazolin-5-one (**20**).[16] The ultraviolet spectrum of **19** showed an absorption at 254 mμ (ε 3530) in 95% ethanol compared with that of **20** which shows a peak at 251 mμ (ε 4040) in cyclohexane.[16] The pmr spectrum of **19** exhibited an isopropyl doublet at 1.02 ppm, J = 7 Hz, two equivalent methyls at 1.61 ppm, and a ring methyl at 2.16 ppm. This evidence would be consistent with the hydrogenolysis product of **7** but not a hydrogenolysis product of **18**.

It may be postulated that the most electronegative nitrogen binds to the diene to give the most stable biradical **21** which ring closes to form the more favorable five-membered ring system.



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An unsymmetrical diene such as α-phellandrene may give two isomeric adducts upon reaction with an unsymmetrical pyrazol-3-one, but no evidence was observed for the formation of two isomers on addition of **3b** to α-phellandrene to give **14**. The structure of **14** is arbitrary since no conclusive evidence has been found to indicate a preferred structure. The downfield bridgehead hydrogen (5.18 ppm) is resolvable into four peaks of equal intensity separated by 3 Hz each. While this may be more consistent with the above structure, the assignment of the downfield proton to the N-1 hydrogen, though reasonable, is not definite. Splitting of the bridgehead hydrogen by a methylene group has not been resolved.[22]

The adducts which formed with **3** and cyclic dienes or cycloheptatriene show a bathochromic shift of the ultraviolet absorption maxinum which may be attributed to transannular interaction between the chromophore and the carbon–carbon double bonds. The *endo* configuration of adducts formed in the Diels–Alder reaction of this dienophile places these bonds in close proximity to the chromophore. The greater strain of the cyclopentadiene adducts would force these bonds closer together than in the cyclohexadiene adducts.

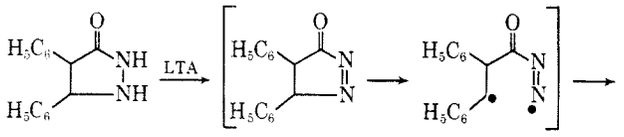
Catalytic hydrogenation of **11** gave 8-methyl-1,4-ethano-1,2,3,4-tetrahydropyrazolo[1,2-*a*]pyridazin-6-one (**22**). The reduction of the double bond shifted the ultraviolet maximum from 270 mμ in **11** to 254 mμ in **22**. Hydrogenation of (**13**) gave 8-phenyl-1,4-methano-1,2,3,4-tetrahydropyrazolo[1,2-*a*]pyridazin-6-one (**23**) and resulted in a shift in the ultraviolet spectral absorption taken in 95% ethanol from 271 mμ and a shoulder at 305 mμ in **13** to a peak at 258 mμ and a shoulder at 310 mμ in **23**. In cyclohexane, the shift is from 257 and 326 mμ (sh) in **13** to 254 and 310 mμ (sh) in **23**. It is evident that the nonconjugated π bonds facilitate the absorptions in the phenylpyrazolinone ring but these interactions vary with the polarity of the solvent. The absorption of the polarized chromophore is enhanced in the more polar solvent.

The adduct **15** had previously been prepared by trapping the intermediate pyrazol-3-one (**3c**) with cyclopentadiene.[14] The same intermediate was obtained in our laboratory by the oxidation of **3a** with

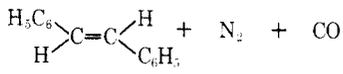
(22) J. E. Anderson and J. M. Lehn, *J. Am. Chem. Soc.*, **89**, 81 (1967).

lead tetraacetate. The cyclopentadiene adduct **15** showed a melting point and pmr spectrum which agreed fully with the reported values.

An attempt was made to trap the acylazo compound, 3,4-diphenyl-1-pyrazolin-5-one (**25**). Oxidation of 3,4-diphenylpyrazolidin-5-one (**24**) with lead tetraacetate at -30° in methylene chloride gave **25** which decomposed with evolution of nitrogen and carbon monoxide to give *trans*-stilbene. The azo compound **25** decomposed before it could tautomerize to **1c** or before it would undergo adduction in the presence of cyclopentadiene. The decomposition probably gave the benzylic radical as a first step which would allow the loss of nitrogen and carbon monoxide to give the observed *trans*-stilbene in 80% yield. The only other product isolated in the reaction was a small amount of cyclopentadiene diacetate. Both compounds were identified by comparing their infrared spectra with those of authentic samples.



24 **25**



The substituted pyrazol-3-ones are thus readily available and easily prepared intermediates which exhibit moderate reactivity among the *cis*-azodienophiles. Their adducts, besides showing interesting spectral absorptions, undergo some unusual reactions of synthetic value. Work on the chemistry of these adducts is currently under investigation.

Experimental Section[23]

Synthesis of 3-Methyl-2-pyrazolin-5-one (1a).—To a solution of 130 g (1.0 mole) of ethyl acetoacetate in 200 ml of 95% ethanol, 55 g (1.0 mole) of 85% hydrazine hydrate was added slowly with stirring at room temperature. Stirring was continued for 1 hr after the addition was complete. Cooling in an ice bath caused the precipitation of 89 g (90%) of the **1a**, mp 223° (lit.[24] mp 221–224°), which was used without further purification.

Synthesis of 3-Phenyl-2-pyrazolin-5-one (1b).—The above procedure was used with 192 g (1.0 mole) of ethyl benzoylacetate in 100 ml of 55% ethanol and 55 g (1.0 mole) of 85% hydrazine hydrate in 100 ml of 95% ethanol. Cooling yielded 130 g (80%) of **1b**, mp 245° (lit.[25] mp 244–245°), which was used without further purification.

Synthesis of 3,4-Diphenyl-2-pyrazolin-5-one (1c).—To a solution of 12 g of sodium metal in 200 ml of absolute ethanol was added a mixture of 85.0 g (0.56 mole) of ethyl benzoate and 58.6 g (0.5 mole) of phenylacetonitrile with stirring. The mixture was refluxed for 3 hr and the ethanol removed by distillation as 200 ml of dry toluene was added. The toluene mixture was poured into 500 ml of water and this mixture was neutralized with acetic acid. The toluene layer was washed with water, dried over anhydrous magnesium sulfate and evaporated under vacuum to 100 ml. On cooling 75 g (65%) of 2-phenylbenzoylacetonitrile precipitated as white solid, mp 94–95° (lit.[26] mp 90°).

To 75 ml of concentrated sulfuric acid was added rapidly 20 g (0.09 mole) of phenylbenzoylacetonitrile. This solution was poured into 500 ml of a crushed ice–water mixture with rapid stirring. On neutralization with sodium hydroxide, 16 g (75%) of phenylbenzoylacetamide, crude mp 150–155° (lit.[26] mp 178°), was obtained on filtration.

A solution of 8 g of hydrazine hydrate, 50 ml of 95% ethanol, 50 ml of water, and 16 g (0.007 mole) of the above amide was refluxed for 8 hr. Ammonia was evolved. The solution was concentrated to 50 ml and neutralized with acetic acid to precipitate 8 g (50%) of **1c**. Crystallization from a benzene–ethanol solution gave 6 g of the white solid (**1c**), mp 194–195°.

1,4-Diphenyl-8-methyl-1,4-dihydropyrazolo[1,2-*a*]pyridazin-6-one (8). General Procedure for the Diels–Alder Reactions.—A mixture of 4.9 g (0.05 mole) of **1a** and 10.3 g (0.05 mole) of 1,4-diphenylbutadiene in 200 ml of methylene chloride was cooled to −10°. A total of 23 g of lead tetraacetate was added with stirring to the solution over a period of 15–30 min. The reaction mixture was stirred for 3 hr after which a negative lead tetraacetate test was observed. The reaction mixture was washed with 50 ml of a saturated sodium carbonate solution, filtered, and washed again with 100 ml of water. (Some of the adducts are slightly water soluble.) The methylene chloride layer was then dried over molecular sieve (or anhydrous sodum sulfate), filtered, and evaporated to give 14.7 g (96%) of the light yellow solid (**8**), mp 160–165°. Recrystallization of the solid from a 4:1 mixture of chloroform and petroleum ether gave a 78% yield of the pure white solid (**8**), mp 176–177°.

Anal. Calcd for $C_{20}H_{18}N_2O$: C, 79.96; H, 5.99; N, 9.66. Found: C, 79.81; H, 5.86; N, 9.61.

2,3,8-Trimethyl-1,4-dihydropyrazolo[1,2-*a*]pyridazin-6-one (9).—From a mixture of 0.05 mole each of 2,3-dimethylbutadiene (**1a**) and lead tetraacetate was obtained 8.0 g (88%) of **9** on evaporation of the solvent and drying under vacuum. Sublimation of 1 g at 90° (0.55 mm) yielded 0.7 g of **9**, mp 89–91°. Resublimation afforded an analytically pure sample, mp 90–92°. The adduct may be crystallized from carbon tetrachloride.

Anal. Calcd for $C_{10}H_{14}N_2O$: C, 67.39; H, 7.92. Found: C, 67.26; H, 7.85.

8-Methyl-1,4-methano-1,4-dihydropyrazolo[1,2-*a*]pyridazin-6-one (10).—This reaction was carried out at −40° to inhibit the dimerization of the cyclopentadiene. From a mixture of 0.2 mole each of freshly distilled cyclopentadiene (**1c**) and lead tetraacetate was obtained 17.5 g (53%) of **10**. Sublimation of 1 g at 75° (0.5 mm) yielded 0.8 g of compound **10**, mp 109.5–110°. The adduct may be crystallized from carbon tetrachloride.

Anal. Calcd for $C_9H_{10}N_2O$: C, 66.64; H, 6.22; N, 17.27. Found: C, 66.74; H, 6.34; N, 17.24.

At temperatures above −10° the lead tetraacetate reacts with the cyclopentadiene and with **1a**. A 5% yield of *trans*-cyclopenten-3,4-diacetate, bp 76° (0.5 mm), $n^{22}D$ 1.5040 (lit.[27] bp 58°) (1.0 mm), was obtained on reaction at −10°.

8-Methyl-1,4-ethano-1,4-dihydropyrazolo[1,2-*a*]pyridazin-6-one (11).—From a mixture of 0.05 mole each of 1,3-cyclohexadiene (**1a**) and lead tetraacetate was obtained 6.5 g (74%) of a heavy yellow oil. Sublimation of 6.2 g at 90° (0.5 mm) gave 4.2 g of a clear oil which solidifies on standing. Resublimation gave a white solid, mp 93–94°.

Anal. Calcd for $C_{10}H_{12}N_2O$: C, 68.16; H, 6.86; N, 15.90: Found: C, 67.86; H, 7.12; N, 16.13.

2,3-Cyclopropa[*d*]1,4-ethano-8-methyl-1,2,3,4-tetrahydropyrazolo[1,2-*a*]-pyridazin-6-one (12).—From a mixture of 0.1 mole each of freshly distilled cycloheptatriene (**1a**) and lead tetraacetate was obtained 9.2 g (49%) of an orange oil (**12**). The oil was crystallized with difficulty from carbon tetrachloride to give a 10% yield of a colorless solid, mp 61–62°. Sublimation at 50° (0.2 mm) gave pure (**12**), mp 91–92°.

Anal. Calcd for $C_{11}H_{12}N_2O$: N, 14.88. Found: N, 15.07.

8-Phenyl-1,4-methano-1,4-dihydropyrazolo[1,2-*c*]pyridazin-6-one (13).—From a mixture of 0.2 mole each of freshly distilled cyclopentadiene (**1b**) and lead tetraacetate was obtained 33 g (75%) of **13**, mp 139–144°. Recrystallization from cyclohexane gave pure **13**, mp 143–144°.

Anal. Calcd for $C_{14}H_{12}N_2O$: C, 74.98; H, 5.39; N, 12.49: Found: C, 74.78; H, 5.26; N, 12.73.

(23) Boiling points and melting points are uncorrected. Microanalyses were performed by Alfred Bernhardt, Mülheim, Germany, and Galbraith Laboratories, Inc., Knoxville, Tenn. The infrared spectra were measured with a Perkin-Elmer Model 137 double-beam spectrophotometer. The ultraviolet spectra were taken on a Cary Model 14 spectrophotometer and the nmr spectra were obtained on a Varian Model A-60 at 60 Mc with deuteriochloroform as solvent and tetramethylsilane as an internal standard.

(24) L. A. Carpino, *J. Am. Chem. Soc.*, **80**, 599 (1958).

(25) C. D. Gutsche and M. Hillman, *ibid.*, **76**, 2236 (1954).

(26) O. Atkinson, O. Ingham, and O. Thorpe, *J. Chem. Soc.*, **91**, 592 (1916).

(27) F. V. Brutcher and F. J. Vara, *J. Am. Chem. Soc.*, **78**, 5895 (1956).

2-Methyl-8-phenyl-1,4-(2′-isopropylethano)-1,4-dihydropyrazolo[1,2-*a*]pyridazin-6-one (14).—From a mixture of 0.1 mole each of freshly distilled α-phellandrene (**1b**) and lead tetraacetate was obtained 24.3 g (82%) of crude solid (14). Recrystallization from cyclohexene yielded pure **14**, mp 176–178°.

Anal. Calcd for $C_{19}H_{22}N_2O$: C, 77.55; H, 7.48; N, 9.52. Found: C, 77.59; H, 7.50; N, 9.56.

An excess of α-phellandrene will cause the crude product to come out as an oil.

7,8-Diphenyl-1,4-methano-1,4-dihydropyrazolo[1,2-*a*]pyridazin-6-one (15).—From a mixture of 0.004 mole each of freshly distilled cyclopentadiene (**1c**) and lead tetraacetate was obtained 0.8 g (65%) of **15**. Recrystallization from cyclohexane gave pure **15**, mp 150–153° (lit.[15] mp 149–151°).

Attempted Reaction of Other Dienes with 3a.—In the reactions where **1a** was oxidized in the presence of anthracene, 1,3-cyclooctadiene, and *trans*-muconic acid no adduct was observed. The lead tetraacetate reacted with **1a** presumably for **3a** which decomposed without addition to the dienes. In each case a large fraction of the unreacted diene was recovered, no **1a** being isolated.

Reaction of Bicycloheptadiene with Lead Tetraacetate.—From a mixture of 0.1 mole each of freshly distilled bicycloheptadiene (**1a**) and lead tetraacetate was obtained 9 g (30%) of 2-*exo*-7-*syn*-norbornane-2,7-diacetate: bp 92–96° (0.5 mm); $n^{25}D$ 1.4700 (lit.[21] bp 96–98° (3.0 mm); $n^{20}D$ 1.4690). Some nonvolatile material could not be distilled. Ninety per cent of the unreacted **1a** was recovered. Concurrent addition of bicycloheptadiene and lead tetraacetate in a methylene chloride solution to **1a** was unsuccessful in causing preferential oxidations of **1a**.

3,3,6-Trimethyl-2-isobutenyl-2-hydropyrazolo[2,3-*b*]-1,3-oxazole (18).—From a mixture of 0.05 mole each of 2,5-dimethyl-2,4-hexadiene (**1a**) and lead tetraacetate was obtained 7.0 g (70%) of (**18**). Distillation at 49° (0.1 mm) gave **18**, $n^{30}D$ 1.4410, in an over-all yield of 63%.

Anal. Calcd for $C_{12}H_{18}N_2O$: C, 69.87; H, 8.80. Found: C, 69.98; H, 8.97.

Catalytic hydrogenation of 0.3 g of **18** over 5% platinum on charcoal led to the absorption of 2.3 equiv of hydrogen at 1 atm pressure and 33°. A 66% yield of **19** was obtained. The spectrum of the product was consistent with the above structure (*vide infra*).

8-Methyl-1,4-ethano-1,2,3,4-tetrahydropyrazolo[1,2-*a*]pyridazin-6-one (22).—To a slurry of 0.1 g of 5% platinum on carbon in 25 ml of 95% ethanol was added a solution of 3.0 g (0.017 mole) of **11** in 25 ml of 95% ethanol. The slurry was stirred under hydrogen at 1 atm and 23° for 20 hr. After uptake ceased at 410 ml, the catalyst was filtered and the solvent evaporated off to give 3.0 g (98%) of **22**. Sublimation at 70° (0.05 mm) yielded pure **22**, mp 61–62°.

Anal. Calcd for $C_{10}H_{14}N_2O$: N, 15.72. Found: N, 15.38.

8-Phenyl-1,4-methano-1,2,3,4-tetrahydropyrazolo[1,2-*a*]pyridazin-6-one (23).—To a slurry of 0.1 g of 5% palladium on carbon in 25 ml of benzene was added a solution of 5.0 g (0.022 mole) of **13** in 100 ml of benzene. The slurry was stirred under hydrogen at 1 atm and 25° for 20 hr. After uptake ceased at 527 ml, the catalyst was removed by filtration and the solvent evaporated to give 5.0 (98%) of **23**. Crystallization from benzene–cyclohexane gave 3.0 g (70%) of pure **23**, mp 148–149°.

Anal. Calcd for $C_{14}H_{14}N_2O$: C, 74.34; H, 6.29; N, 12.39. Found: C, 74.05; H, 6.34; N, 12.19.

3,4-Diphenylpyrazolidin-5-one (24).—Ethyl α-phenylcinnamate was prepared by the method of Sudborough and Loyd.[28] A 50% yield was obtained after distillation: bp 70–75° (75 μ) (lit.[28] bp 163–165° (1 mm)). The ethyl α-phenylcinnamate was converted to **24** by the method of Carpino.[29] A 70% yield was obtained which may be crystallized from benzene to give a white solid (**24**), mp 136–137° (lit.[29] mp 139–141°).

Oxidation of 24 with Lead tetraacetate in the Presence of Cyclopentadiene.—The procedure of the previous oxidation was used herein and from a mixture of 0.009 mole each of freshly distilled cyclopentadiene (**24**) and lead tetraacetate was obtained 1.2 g of *trans*-stilbene, mp 125°. The infrared spectrum of the crude product obtained from the evaporation of the methylene chloride showed peaks for *trans*-stilbene.

Registry No.—**7**, 14181-54-5; **8**, 14181-55-6; **9**, 14181-56-7; **10**, 14264-76-7; **11**, 14264-77-8; **12**, 14264-78-9; **13**, 14181-57-8; **14**, 14271-47-7; **15**, 1162-74-9; **18**, 14181-59-0; **22**, 14319-53-0; **23**, 14181-60-3.

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The Cyclization of Nitriles by Halogen Acids. II. A New Synthesis of Substituted 3H-Azepines

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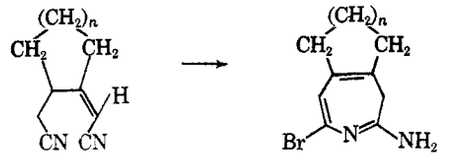
The treatment of 2-aryl- (or alkyl-) 1,4-dicyano-1-butenes (III) having *syn*-nitrile groups with hydrogen bromide in anhydrous media leads to 2-amino-5-aryl- (or alkyl-) 7-bromo-3H-azepines in good yield. However, a new attempt to obtain the corresponding azepine from *cis*-1,4-dicyano-1-butene was once again unsuccessful, despite the fact that 1,4-dicyano-2-methylbutene-1 did give the expected azepine derivative. The dinitriles required for the cyclization studies were synthesized by conventional methods and their stereochemistry was assigned by comparing their nmr spectra with those of suitable model compounds. The previous geometrical assignments of the *cis*- and *trans*-1,4-dicyano-1-butenes were found to be incorrect.

The synthesis of a series of azepine derivatives represented by II ($n = 1, 2, 3,$ or 4) was described in the preceding paper of this series.[1] These compounds



I II

were obtained by treating the corresponding dinitriles (I) with hydrogen bromide under anhydrous conditions, followed by neutralization of the initially formed hydrobromide salts. The success achieved in these cyclizations encouraged us to attempt the cyclization of some purely acyclic dinitriles despite the fact that neither adiponitrile, 2,5-diphenyladiponitrile, nor yet a mixture of *cis*- and *trans*-1,4-dicyano-1-butenes had led to azepine derivatives[2] under the conditions used for the preparation of II.

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