[CONTRIBUTION FROM THE RESEARCH LABORATORIES OF THE UPJOHN COMPANY, KALAMAZOO, MICH.]

Derivatives of *trans*-3,7-Diazatricyclo[4.2.2.$2^{2,5}$]dodecane

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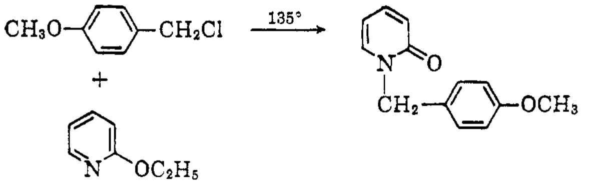
The photodimerization of variously substituted 2-pyridones has yielded the novel 3,7-diazatricyclo[4.2.2.$2^{2,5}$]dodeca-9,11-diene-4,8-diones. These tricyclic heterocycles have been catalytically and chemically reduced to afford the parent diamines. The n.m.r. spectra of the various photodimers are discussed.

The synthesis of substituted cyclobutanes by photochemical dimerization of appropriately activated olefins[1,2] or by intramolecular cyclization of suitably constructed dienes[3-11] is undergoing active exploitation. Indeed, the irradiation of 2-pyridone and 1-methyl-2-pyridone appeared on the basis of the report by Taylor and Paudler[12] to be an extension in practice of light-induced dimerizations to cyclobutane systems. However, reinvestigation of this reaction indicated that this was not the situation and a recent communication from this Laboratory[13] reported that the ultraviolet irradiation of 2-pyridone and 1-methyl-2-pyridone did not afford the cyclobutane derivatives previously claimed[12] but rather produced dimeric products containing a novel tricyclic octadiene system. These photodimers (the *trans*-3,7-diazatricyclo[4.2.2.$2^{2,5}$]-dodeca-9,11-diene-4,8-diones) probably result by attack of a photochemically activated molecule (a 3,6-diradical) on a second, unactivated molecule.[14] Other workers[15,16] have independently arrived at the same structure for these pyridone photodimers. We wish now to elaborate further on the generality of the reaction, some chemical modifications of the dimers and more subtle refinements of the interpretation of resonance lines associated with the various protons of the photoproducts in their n.m.r. spectra.

Generality of the Reaction.—Our unexpected results with the irradiation of 2-pyridone and 1-methyl-2-pyridone stimulated our interest in the photochemistry of other substituted 2-pyridones. The compounds studied were 1-substituted 2-pyridones possessing groups of increasing steric bulk at the 1-position and polysubstituted 2-pyridones. In the latter category, 1,*x*-dimethylpyridones were chosen for purposes of uniformity and simplification of n.m.r. spectral data.

Irradiation of the various 2-pyridone substrates listed in Table I in aqueous or aqueous alcoholic solution afforded the corresponding *trans*-3,7-diazatricyclo[4.2.-2.$2^{2,5}$]dodeca-9,11-diene-4,8-diones (I–XII, Table I)[17] in good yield. The dimers either crystallized from solution as the reaction proceeded or were readily extractable by means of an organic solvent (*cf.* Experimental). Structures of the photoproducts were conclusively established by elemental analyses, molecular weight determinations and n.m.r. spectral interpretations (see below). Our unpublished results on the dimer of 1,6-dimethyl-2-pyridone suggests that it does not possess a *trans-anti* structure.[15,18]

The 1-(*p*-methoxybenzyl)-2-pyridone utilized in the preparation of XII was obtained by the reaction of anisyl chloride and 2-ethoxypyridine according to the procedure of Paquette and Nelson.[19] The quantitative



yield of 2-pyridone obtained in this instance is not surprising in view of the high reactivity of the anisyl chloride.

Quaternization of the dibasic dimer XI with methyl iodide in ethanol readily furnished the dimethiodide XIII.

The varying yields of photodimers obtained with the 1,*x*-dimethylpyridones[20] leaves much to be desired when a correlation of substituent location with ease of dimerization is attempted. However, the discrepancy[15,18] observed in the case of 1,6-dimethyl-2-pyridone forces one to conclude that the site of the substituent does in fact have some effect on the course of the photodimerization. The role of steric and inductive influences in organic photochemistry remains to be clarified.

Catalytic reduction of the photoproducts readily yielded the corresponding *trans*-3,7-diazatricyclo[4.2.2.-$2^{2,5}$]dodecane-4,8-diones (see Table II). A discussion of some of the ground state properties of XV in solution at room temperature has already been presented[13]; generalization of these features can be logically extended to the other members of the series.

The parent bases, namely the *trans*-3,7-diazatricyclo-[4.2.2.$2^{2,5}$]dodecanes (XXI), can be readily produced by chemical reduction of compound types XIV–XIX with lithium aluminum hydride. Thus, interaction of XV and XIX with lithium aluminum hydride afforded, after treatment of the resulting amines with ethereal hydrogen chloride, XXIa and XXIb in yields of 98.5% and 99.0%, respectively. When excess methyl iodide and XXIa (as the free base) were refluxed in ethanol for three hours, a 97.7% yield of the monomethiodide XXII was obtained. The dimethiodide XXIII was synthe-

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[1] For a review of this subject matter, *cf.* A. Mustafa, *Chem. Revs.*, **51**, 1 (1952).

[2] J. M. Bruce, *J. Chem. Soc.*, 2782 (1962), and leading references cited therein.

[3] E. J. Forbes, *ibid.*, 3864 (1955).

[4] G. Büchi and I. M. Goldman, *J. Am. Chem. Soc.*, **79**, 4741 (1957).

[5] O. L. Chapman and co-workers, *ibid.*, **80**, 6685 (1958); **82**, 3642 (1960); **84**, 1213 (1962); *J. Org. Chem.*, **26**, 4185 (1961); **27**, 2291 (1962).

[6] W. G. Dauben and G. J. Fonken, *J. Am. Chem. Soc.*, **79**, 2971 (1957); **81**, 4060 (1959).

[7] G. Büchi and E. M. Burgess, *ibid.*, **82**, 4333 (1960); *cf.* also J. J. Hurst and G. H. Whitman, *Proc. Chem. Soc.*, 116 (1961).

[8] O. L. Chapman and D. J. Pasto, *Chemistry & Industry*, 53 (1961).

[9] W. G. Dauben and R. L. Cargill, *Tetrahedron*, **12**, 186 (1961).

[10] J. Rigaudy and P. Courtot, *Tetrahedron Letters*, **No. 3**, 95 (1961).

[11] G. J. Fonken, *Chemistry & Industry*, 1575 (1961).

[12] E. C. Taylor and W. W. Paudler, *Tetrahedron Letters*, **No. 25**, 1 (1960).

[13] G. Slomp, F. A. MacKellar and L. A. Paquette, *J. Am. Chem. Soc.*, **83**, 4472 (1961).

[14] The authors are indebted to a referee for stating that this mechanism is much more probable than the coupling of two pairs of diradicals (which we have previously suggested).[13]

[15] W. A. Ayer, R. Hayatsu, P. deMayo, S. T. Reid and J. B. Stothers, *Tetrahedron Letters*, **No. 18**, 648 (1961).

[16] E. C. Taylor, R. O. Kan and W. W. Paudler, *J. Am. Chem. Soc.*, **83**, 4484 (1961).

[17] Although the 3,7-diazatricyclo[4.2.2.$2^{2,5}$]dodeca-9,11-diene-4,8-diones have been described previously in various spatial arrangements,[13,15-16] and properly so, we have sacrificed stereochemical accuracy for clarity and have adopted a more or less planar formula for use in this manuscript.

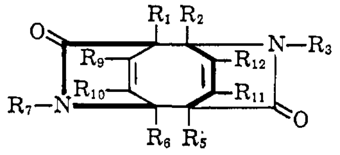
[18] Although the n.m.r. spectrum of this material rules out the *trans-anti* structure, rigorous proof of an alternative structure will not be made at this time.

[19] L. A. Paquette and N. A. Nelson, *J. Org. Chem.*, **27**, 1085 (1962).

[20] The photolysis of 1,6-dimethyl-2(1H)-pyridone under similar conditions afforded a 52.0% yield of dimer.

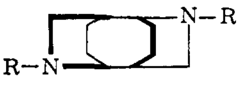
TABLE I

trans-3,7-DIAZATRICYCLO[4.2.2.$2^{2,5}$]DODECA-9,11-DIENE-4,8-DIONES

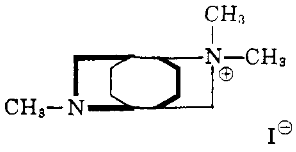


Compd. no.	2-Pyridone substrate	R_1	R_2	R_3	R_5	R_6	R_7	R_9	R_{10}	R_{11}	R_{12}
I	2-Pyridone	H	H	H	H	H	H	H	H	H	H
II	1-Methyl[b]	H	H	CH_3	H	H	CH_3	H	H	H	H
III	1-Ethyl[c]	H	H	CH_2CH_3	H	H	CH_2CH_3	H	H	H	H
IV	1-Propyl[c]	H	H	$CH_2CH_2CH_3$	H	H	$CH_2CH_2CH_3$	H	H	H	H
V	1-Allyl[d]	H	H	$CH_2CH{=}CH_2$	H	H	$CH_2CH{=}CH_2$	H	H	H	H
VI	1-Isopropyl[c]	H	H	$CH(CH_3)_2$	H	H	$CH(CH_3)_2$	H	H	H	H
VII	1,3-Dimethyl[e]	CH_3	H	CH_3	CH_3	H	CH_3	H	H	H	H
VIII	1,5-Dimethyl[e]	H	H	CH_3	H	H	CH_3	H	CH_3	H	CH_3
IX	1,4-Dimethyl[f]	H	H	CH_3	H	H	CH_3	CH_3	H	CH_3	H
X	1-Hydroxyethyl[g]	H	H	CH_2CH_2OH	H	H	CH_2CH_2OH	H	H	H	H
XI	1-(2-Diethylamino-ethyl)[g]	H	H	$CH_2CH_2NEt_2$	H	H	$CH_2CH_2NEt_2$	H	H	H	H
XII	1-(*p*-Methoxybenzyl)	H	H	$CH_2C_6H_4\text{-}p\text{-}OCH_3$	H	H	$CH_2C_6H_4\text{-}p\text{-}OCH_3$	H	H	H	H
XIII		H	H	$I^{\ominus}\ -CH_2CH_2\underset{\oplus}{\overset{CH_3}{N}}Et_2$	H	H	$I^{\ominus}\ -CH_2CH_2\underset{\oplus}{\overset{CH_3}{N}}Et_2$	H	H	H	H

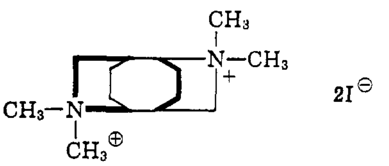
sized by heating XXII in excess methyl iodide for eight hours at 120–130° (autoclave).[21]



XXIa, R = $CH_3 \cdot 2HCl$
b, R = $-CH_2CH_2N(C_2H_5)_2 \cdot 4HCl$



XXII



XXIII

3-Chloro-2-pyridone,[22] 6-chloro-2-pyridone[23] and 1-(*m*-aminophenyl)-2-pyridone[24] failed to undergo reaction under the photolytic conditions employed.

Nuclear Magnetic Resonance Spectra.[25]—The assignment of structure II to the photodimer of 1-methyl-2-pyridone on the basis of n.m.r. data has been reported earlier.[13] Similar studies on the analogous compounds described above have permitted other conclusions concerning conformational mobility and precise assignment of proton resonance lines to be reached.[26]

The dimer of 1,4-dimethyl-2-pyridone (IX) gave an n.m.r. spectrum (Fig. 1) closely related to that of II.[27] Present were four types of hydrogens of relative abundances 2,4,6 and 6, from area measurements, based on the dimeric empirical formula. The least shielded multiplet center at 375 c.p.s., in the vinyl hydrogen region, was two overlapping quintets; closer examination revealed that it was a doublet with two additional small splittings which were attributed to the tertiary protons at C_1 and C_5 and to the methyl hydrogens at C_9 and C_{11}, both β-coupled through the double bond. The tertiary hydrogens, absorbing at 243 and 205 c.p.s. in the allylic hydrogen region, yielded a pattern embodying certain features of the spectrum of II. They formed an AB multiplet each partner having one additional split. The N-methyl absorption at 173 c.p.s. remained unchanged from the parent spectrum and the new C-methyl absorption at 111 c.p.s. was manifest as a doublet in accordance with the splitting by the vinyl proton.

The magnitude of the coupling constants observed in the tertiary hydrogen multiplets permitted specific proton assignments. The 7 c.p.s. coupling was of a magnitude to suggest interaction with the vinyl hydrogen attached to an adjacent carbon atom. Hence this absorption was identified with the tertiary hydrogens at C_2 and C_6. The 2 c.p.s. coupling of the other tertiary hydrogen absorption was in agreement with that expected for an interaction with a vinyl proton attached to a β-carbon atom and coupled through a double bond. This absorption was accordingly identified with the protons at C_1 and C_5. These assignments can be extrapolated, by analogy, to the absorptions found in the spectrum of II.[13]

The dimer of 1,3-dimethyl-2-pyridone (VII) furnished a spectrum (Fig. 2) which was closely related to that of the parent dimer II[27] and the relationships of the hydrogen interactions were the counterparts of those observed in the spectrum of IX. By analogous reasoning,

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[21] The authors are indebted to M. A. Rebenstorf for carrying out this reaction.

[22] M. P. Cava and N. K. Bhattacharyya, *J. Org. Chem.*, **23**, 1287 (1958).

[23] Purchased from the Aldrich Chemical Co., Milwaukee, Wis.

[24] J. V. Scudi, D. B. Reisner, S. J. Childress and L. A. Walter, U. S. Patent 2,947,755 (Aug. 2, 1960). We are indebted to Wallace and Tiernan, Inc., for a generous supply of this material supplied through the courtesy of Dr. Charles E. Hough.

[25] Spectra were obtained on dilute solutions in deuteriochloroform with a Varian 4300-2 spectrometer operating at 60 Mc. The spectra were calibrated by the audiofrequency side-band technique against internal tetramethylsilane standard.

[26] The assignment of the *trans-anti* structure to II was based on dipole moment (0.07 D. in $CHCl_3$)[12] and n.m.r. data.[13] The *trans* formulation is required because of the AB multiplet patterns observed in the vinyl and tertiary hydrogen absorptions in the n.m.r. spectrum.[12] The *anti* assignment is necessitated by the negligible dipole moment and is required to explain the shielding differences observed for the two sets of vinyl hydrogen atoms. In the *anti* form the 9- and 11-hydrogen atoms are in the region of additional shielding generated by the anisotropy cone of the nearby carbonyl groups. In the *syn* configuration, the carbonyl groups would be too distant to produce such an effect. The *trans-anti* assignment can be extended readily to the other dimers discussed herein by analogous reasoning (see Fig. 1–4).

[27] The photodimeric materials derived from 2-pyridone (I and XIV) were too insoluble to allow for n.m.r. spectral determinations. The dimer of 1-methyl-2-pyridone (II) is therefore referred to herein as the parent material for n.m.r. studies.

Hr. irrad.	Yield, %[a]	M.p., °C.	Recrystn. solv.	Analyses, % Calcd. C	H	N	Mol. wt.	Found C	H	N	Mol. wt.	Isol. proc.
6	13.1	224.5–226.5	HOAc	See reference 14								A
48	43.2	222.5	$EtOH-Et_2O$	66.03	6.47	12.84	218	65.89	6.27	12.73	231	B
48	41.5	208–209	C_6H_6–hexane	68.27	7.37	11.37	246	68.50	7.62	11.34	260	B
40	12.3	198–199	$EtOH-Et_2O$	70.04	8.08	10.21	274	70.00	8.02	10.23	272	A
32	13.0	198	$EtOH-Et_2O$	71.09	6.71	10.36	270	71.53	6.67	10.50	277	A
96	24.0	228–229	C_6H_6–EtOH–hexane	70.04	8.08	10.21	274	70.22	8.30	10.38	285	B
16	14.4	191	$EtOH-Et_2O$	68.27	7.37	11.37	246	68.17	7.32	11.14	237	A + B
16	58.3	240–241	Aq. $EtOH-Et_2O$	68.27	7.37	11.37	246	68.00	7.52	11.08	299	A + B
16	19.0	241	Aq. $EtOH-Et_2O$	68.27	7.37	11.37	246	68.09	7.03	11.18	239	A + B
16	18.6	229	H_2O	60.42	6.52	10.07	..	60.45	6.88	9.88	..[h]	A
16	11.7	196–197	C_6H_6–hexane	68.00	9.34	14.42	388	68.00	9.21	14.20	377	A
20	7.25	232	DMF	72.54	6.09	6.51	..	72.22	5.93	6.80	..[h]	A
..	99.8	235–236	Aq. $EtOH-Et_2O$	42.86	6.30	8.33	..	42.73	6.40	8.19	..	..[i]

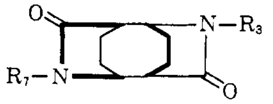
[a] In all photolyses, the aqueous solution after appropriate work-up can be reirradiated repeatedly and excellent total yields obtained. [b] Purchased from the K and K Laboratories, Inc., Jamaica, N. Y. [c] C. Rath, *Ann.*, **489**, 107 (1931). [d] B. I. Mikhant'ev, E. I. Fedorov, A. I. Kucherova and V. P. Potapova, *Zhur. Obshchei, Khim.*, **29**, 1874 (1959); *C. A.*, **54**, 8808 (1960). [e] H. L. Bradlow and C. A. Vanderwerf, *J. Org. Chem.*, **16**, 73 (1951). [f] R. Adams and A. W. Schrecker, *J. Am. Chem. Soc.*, **71**, 1186 (1949). [g] K. Miescher and E. Urech, U. S. Patent 1,941,312 (Dec. 26, 1933). [h] Compound too insoluble for determination. [i] See Experimental section.

the specific assignment of the spectral absorptions was accomplished. The absorption of the tertiary hydrogens was displaced upfield by the addition of the angular methyl groups.[28]

The dimer of 1,5-dimethyl-2-pyridone afforded a spectrum (Fig. 3) in agreement with the *trans*-3,7-diazatricyclo[4.2.2.2^{2,5}]doceca-9,11-diene-4,8-dione formulation VIII. The absorptions were similar to those of IX but the tertiary hydrogen absorptions were closer together.

TABLE II

trans-3,7-DIAZATRICYCLO[4.2.2.2^{2,5}]DODECANE-4,8-DIONES



Compd.	R_3, R_7	Yield, %	M.p., °C.	Recrystn. solv.	Formula	Analyses, % Calcd. C	H	N	Found C	H	N
XIV	H	89.0	398–400	HOAc	$C_{10}H_{14}N_2O_2$	61.83	7.27	14.42	61.83	7.18	14.15
XV	$-CH_3$	94.7	284–285			See reference 14					
XVI	$-CH_2CH_2CH_3$	97.0	210–211	$EtOH-Et_2O$	$C_{16}H_{26}N_2O_2$	69.03	9.41	10.06	68.89	9.11	10.28
XVII	$-CH(CH_3)_2$	99.0	247–249	$EtOH-Et_2O$	$C_{16}H_{26}N_2O_2$	69.03	9.41	10.06	69.05	9.19	9.90
XVIII	$-CH_2CH_2OH$	100	230–231.5	H_2O	$C_{14}H_{22}N_2O_4$	59.55	7.85	9.92	59.57	7.56	10.10
XIX	$-CH_2CH_2NEt_2$	100	183–184.5	C_6H_6–hexane	$C_{22}H_{40}N_4O_2$	67.30	10.27	14.27	67.29	10.10	14.12
XX	$-CH_2CH_2\overset{\oplus}{\underset{\substack{\vert \\ CH_3}}{N}}Et_2$ $I^{\ominus}$	99.2	268 (foaming)	$EtOH-Et_2O$	$C_{24}H_{46}I_2N_4O_2$	42.61	6.85	8.28	42.44	6.88	7.93

The presence of two equivalent N-methyl groups (judged to be axially oriented; *cf.* A below) in II was established by the sharp singlet at 168 c.p.s.[13] When the spectrum of the N-propyl analog IV (see Fig. 4) was examined, it was found that the usual vinyl and tertiary proton resonance pattern[13] was present; in addition, the absorptions associated with the propyl side chain appeared normal, except that the two discrete resonance multiplets for the N-methylene groups were present. In addition to the AB section of an ABM_2 multiplet (area 2) at 156 and 143 c.p.s., there was found another N-methylene absorption under one of the tertiary hydrogen multiplets (see Fig. 4). After subtraction of the teritiary proton absorption, the N-methylene resonance peaks remained (area 2) and were readily identified as the $A'B'M_2$ absorption (located at 232 and 218 c.p.s.). This distinction between the two N-methylene species can best be attributed to a difference in side-chain orientation.[29] Since the distribution of the two types of N-methylene groups was approximately equal, it was strongly suggested that the frequency difference was caused by the presence of axial and equatorial conformations of the substituents at the 3,7-positions of the dimer (*cf.* B).[30] The *n*-propyl group in the axial conformation probably absorbs at the higher resonance frequency since molecular models indicate that this orientation places the methylene unit in a region of more positive anisotropy of the nearby carbonyl group.

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(28) J. N. Shoolery and M. T. Rogers, *J. Am. Chem. Soc.*, **80**, 5121 (1958).

(29) Although the application of nuclear magnetic resonance spectroscopy to the solution of organic conformational problems is still in the early stages of development, several useful correlations have already been discovered [*cf.* L. M. Jackman, "Nuclear Magnetic Resonance Spectroscopy," Pergamon Press, New York, N. Y., 1959, p. 115; D. H. R. Barton and G. A. Morrison, *Fort. Chem. Org. Naturstoffe*, **19**, 196 (1961), edited by L. Zechmeister].

(30) Since the one-to-one distribution of resonance peaks indicates that the ratio of the two conformations is only statistically equal, the possibility remains that a mixture of axial–axial, axial–equatorial and equatoriel–equatorial conformers was present in the proper amounts, although this appears somewhat unlikely.

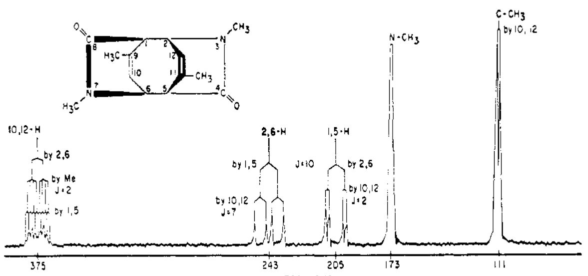


Fig. 1.—N.m.r. spectrum of 1,4-dimethyl-2-pyridone photodimer (IX).[25]

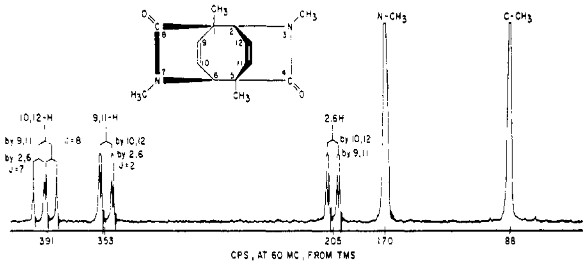


Fig. 2.—N.m.r. spectrum of 1,3-dimethyl-2-pyridone photodimer (VII).[25]

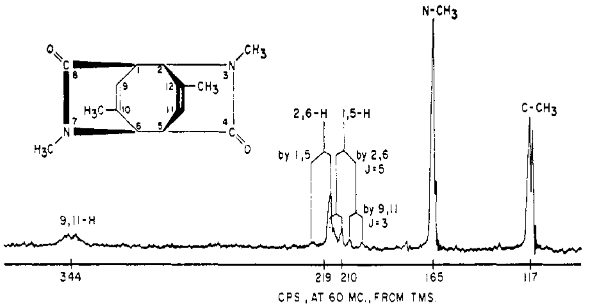
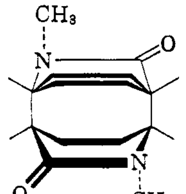
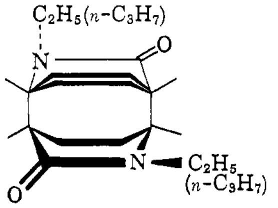
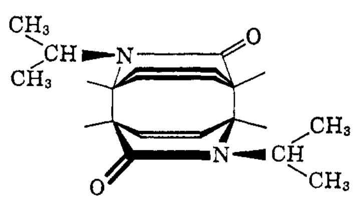


Fig. 3.—N.m.r. spectrum of 1,5-dimethyl-2-pyridone photodimer (VIII).[25]

The identical situations existed when the spectra of the ethyl (III) and diethylaminoethyl (XI) analogs were examined; again in these examples, the axial–equatorial relationship of the groups was evident.







The resonance lines associated with the olefinic and tertiary hydrogen atoms were again present in the spectrum of the isopropyl dimer VI (see Fig. 5). In addition, the two *identical* isopropyl groups showed absorptions attributed to the tertiary isopropyl hydrogens at 274 c.p.s. (septuplet, $J = 7$) and two species of methyl protons, not averaged by rotation, at 63 and 58 c.p.s. (both doublets). These results indicate that the isopropyl groups are in the same conformation, presumably equatorial, *and that steric factors are preventing free rotation of these substituents.*[31]

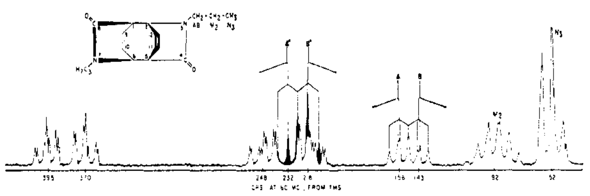


Fig. 4.—N.m.r. spectrum of N-*n*-propyl-2-pyridone photodimer (IV).[25]

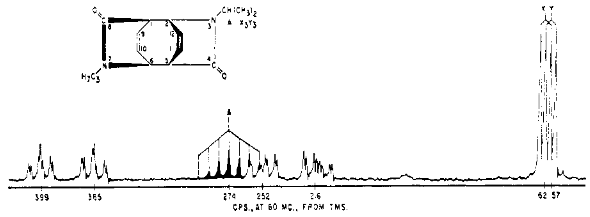


Fig. 5.—N.m.r. spectrum of N-isopropyl-2-pyridone photodimer (VI).[25]

The *trans*-3,7-diazatricyclo[4.2.2.2^{2,5}]dodecane-4,8-diones (XVI–XIX) furnished spectra which were as expected and which supported the axial–equatorial concept as applied to the 3,7-substituents.

To summarize, it appears that as the steric bulk of the 3,7-substituents in the photodimers increases from methyl[27] to ethyl and *n*-propyl (and N,N-diethylaminoethyl), the orientation of these groups passes from a completely axial conformation in the 3,7-dimethyl case to a situation where one group is located axially and the other equatorially. When the size of the substituent is increased to isopropyl (and presumably also larger), a state of complete equatorial alignment is attained with the added limitation of restricted rotation of the side chains.

In an earlier report,[13] an unusual ring conversion between two boat forms of the tetrahydrodimer XV was described. Low temperature n.m.r. spectroscopy was investigated to see if the rate of the ring conversion could be noticeably decelerated. The conversion was slowed enough at −8° to yield an intermediate broadened state.[32] Lower temperatures were not available so that complete synchronization of the previously isolated peaks could be observed.

Conclusion.—The generalized rule[33] that photochemical excitation of conjugated cyclic dienes containing $2n$ annular atoms and $n - 1$ double bonds will induce ring cleavage in many cases (see ref. 33), but also ring tautomerism in special circumstances has been well substantiated in the case of carbocyclic systems. In addition, extrapolation of this rule to heterocyclic systems has been found to be plausible, for the irradiation of 2-pyrones[34] and unsaturated sultones[35] has likewise led to open-chain compounds. However, although the 2-pyridone ring is indeed a heterocyclic system of $2n$ members containing $(n - 1)$ conjugated double bonds, its ultraviolet irradiation furnishes neither an open-chain compound nor a product resulting from a bridging

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[31] Non-equivalence of n.m.r. absorption bands caused by restricted rotation in the vicinity of similar protonic species has also been observed in simpler systems. For example see C. L. Bumgardner, K. S. McCallum and J. P. Freeman, *J. Am. Chem. Soc.*, **83**, 4417 (1961).

[32] We are indebted to Dr. W. Ritchey of Standard Oil Co. (Cleveland, O.) for these low temperature measurements.

[33] (a) D. H. R. Barton, *Helv. Chim. Acta*, **42**, 2604 (1959); (b) P. deMayo, "Advances in Organic Chemistry," Vol. 11, Interscience Publishers, Inc., New York, N. Y., 1960, p. 367.

[34] *Cf.* ref. 33b, p. 393.

[35] E. Henmo, P. deMayo, A. B. M. Abdus Sattar and A. Stoessl, *Proc. Chem. Soc.*, 238 (1961).

reaction, but affords the dimeric 3,7-diazatricyclo$[4.2.2.2^{2,5}]$dodeca-9,11-diene-4,8-diones (see above). The dimerization of the 3,6-diradicals which result in the photoexcited state thus represents a fourth mode of degenerative stabilization of this type of system and may serve to open new synthetic possibilities in cage-type structures.[36,37] This may be represented structurally by the process D → E where X is a nitrogen atom (actually N–R) and Y is a carbonyl group or its imino counterpart. It indeed would be of interest to determine if the process D → E could occur in some carbocyclic systems.

Experimental[38]

1-(*p*-Methoxybenzyl)-2-pyridone.—A mixture of 15.7 g. (0.10 mole) of anisyl chloride and 18.5 g. (0.15 mole) of 2-ethoxypyridine was heated at 135° with stirring for 24 hr. After cooling, the light brown oil was chromatographed directly on Florisil.[39] Elution with hexane removed the excess 2-ethoxypyridine and elution with ether gave 21.5 g. (100%) of a white crystalline solid, m.p. 84–86°. Three recrystallizations of this material from benzene–hexane gave the pure pyridone as fine, white needles, m.p. 84.5–86°.

Anal. Calcd. for $C_{13}H_{13}NO_2$: C, 72.54; H, 6.09; N, 6.51. Found: C, 72.45; H, 5.79; N, 6.60.

General Photolytic Procedure. Method A.—A solution of 0.10 to 0.50 mole of the pyridone in 250–750 ml. of water was irradiated with a 200-watt unfiltered (Pyrex vessel) Hanovia lamp for 16–96 hr. (see Table I). The precipitated crystals were filtered, washed with cold water and dried thoroughly. Two or three recrystallizations of the crude product from the appropriate solvent or solvent mixture afforded the pure photodimers.

Method B.—This procedure differs from method A by the fact that at the completion of the irradiation the aqueous solution was extracted with three 150-ml. portions of chloroform or methylene chloride. The combined organic layers were dried, filtered and evaporated to give a semisolid. Treatment of this residue with benzene–hexane (1:1) and filtration of the cooled mixture afforded the photodimer. Concentration of the filtrate gives monomeric pyridone which can be recycled without further purification.

General Hydrogenation Procedure.—A solution of 5–50 mmoles of the photodimer in 150 ml. of ethanol[40] containing 100–300 mg. of platinum dioxide was hydrogenated in a Parr apparatus at room temperature with an initial pressure of 50 p.s.i. When the uptake of hydrogen ceased, the catalyst was filtered and the filtrate was concentrated. The residual solids were recrystallized from the solvents indicated in Table II.

[(4,8-Dioxo-3,7-diazatricyclo$[4.2.2.2^{2,5}]$dodeca-9,11-diene-3,7-diyl)-diethylene]-bis-[diethylmethylammonium] Iodide (XIII).—To a solution of 3.0 g. (7.73 mmoles) of XI in 30 ml. of ethanol was added 15 ml. of methyl iodide and the solution was refluxed for 1 hr. A solid rapidly separated as the reaction proceeded. The cooled mixture was treated with ether; the white solid was filtered and washed thoroughly with ether. The dried product weighed 5.17 g. (99.8%), m.p. 235–236°. Pure diiodide was obtained as fine white crystals from 80% aqueous ethanol–ether; m.p. 235–236°. For analytical data see Table I.

[(4,8-Dioxo-3,7-diazatricyclo$[4.2.2.2^{2,5}]$dodecane-3,7-diyl)-diethylene]-bis-[diethylmethylammonium] Iodide (XX).—A solution of 3.0 g. (7.73 mmoles) of XIX in 30 ml. of absolute ethanol was treated with methyl iodide (15 ml.) as above. There was obtained 5.15 g. (99.2%) of an off-white solid, m.p. 268° (foaming). Recrystallization of this material from 90% aqueous ethanol–ether gave pure diiodide as small off-white crystals, m.p. 268° (foaming). For analytical data see Table II.

3,7-Dimethyl-3,7-diazatricyclo$[4.2.2.2^{2,5}]$dodecane Dihydrochloride (XXIa).—To a stirred slurry of 19.0 g. (0.50 mole) of lithium aluminum hydride in 350 ml. of dry, purified tetrahydrofuran was added in portions a slurry of 34.4 g. (0.154 mole) of XV in 400 ml. of the same solvent. The resulting mixture was refluxed with stirring for 2 hr. and allowed to stand overnight at room temperature. To the rapidly stirred mixture cooled in ice there was added 19 ml. of water, 57 ml. of 25% sodium hydroxide solution and 19 ml. of water, in that order. The precipitated salts were filtered and washed well with ether and methylene chloride. The combined filtrates were dried, filtered and evaporated to give, after thorough drying, 29.4 g. (98.5%) of pale yellow solid which was converted directly to its dihydrochloride. Recrystallization from ethanol–ether gave pure dihydrochloride as white blades, m.p. 274° (foaming).

Anal. Calcd. for $C_{12}H_{24}Cl_2N_2$: C, 53.93; H, 9.05; N, 10.48. Found: C, 54.04; H, 9.22; N, 10.34.

A 4.60-g. (17.2 mmoles) sample of the dihydrochloride was dissolved in 20 ml. of water and to the solution was added 50 ml. of concentrated ammonium hydroxide. The white solid which separated was extracted with two 100-ml. portions of methylene chloride. The combined organic layers were dried, filtered and evaporated to afford 3.1 g. (94.0%) of white prisms, m.p. 48–48.5° (from hexane).

Anal. Calcd. for $C_{12}H_{22}N_2$: C, 74.17; H, 11.41; N, 14.42. Found: C, 74.45; H, 11.12; N, 14.21.

3,7-Bis-(2-diethylaminoethyl)-3,7-diazatricyclo$[4.2.2.2^{2,5}]$dodecane Tetrahydrochloride (XXIb).—A solution of 6.4 g. (0.163 mole) of XIX in 75 ml. of dry, purified tetrahydrofuran was added dropwise to a slurry of 1.90 g. (0.050 mole) of lithium aluminum hydride in 50 ml. of the same solvent. The stirred mixture was refluxed for 2 hr. and was decomposed while cooled in an ice–water-bath with 2 ml. of water, 6 ml. of 30% sodium hydroxide solution and 2 ml. of water, in that order. The precipitated salts were filtered and washed well with ether. The filtrates were combined and evaporated to give a colorless oil which was directly converted to its tetrahydrochloride with ethereal hydrogen chloride. The while solid was filtered and thoroughly dried to give 8.25 g. (99.0%) of product, m.p. 268–270° dec. Pure tetrahydrochloride was obtained as fine white crystals, m.p. 274° dec., from ethanol–ether.

Anal. Calcd. for $C_{22}H_{48}Cl_4N_4$: C, 51.76; H, 9.48; N, 10.98; equiv. wt., 127.6. Found: C, 51.69; H, 9.48; N, 10.92; equiv. wt., 128.5.

3,3,7-Trimethyl-7-aza-3-azoniatricyclo$[4.2.2.2^{2,5}]$dodecane Iodide (XXII).—A solution of 14.0 g. (0.072 mole) of XXIa (as the free base) in 150 ml. of ethanol was treated with 56.8 g. (0.40 mole) of methyl iodide and the solution was refluxed for 3 hr. Ether (100 ml.) was added and the mixture was cooled. The precipitated solid was filtered and dried to give 23.6 g. (97.7%) of pale yellow solid, m.p. 208–212° dec. This material was recrystallized three times from ethanol to give pure monomethiodide as a white solid, m.p. 214–215° dec.

Anal. Calcd. for $C_{13}H_{25}IN_2$: C, 46.43; H, 7.49; N, 8.33. Found: C, 46.15; H, 7.32; N, 8.14.

3,3,7,7-Tetramethyl-3,7-diazoniatricyclo$[4.2.2.2^{2,5}]$dodecane Diiodide (XXIII).—A slurry of 10.0 g. (0.0298 mole) of XXII in 95 ml. of methyl iodide was heated in an autoclave at 120–130° for 8 hr. The solvent was evaporated and the gummy residue was recrystallized from 90% ethanol–ether. The crystals which formed were filtered and dried to yield 7.6 g. (53.5%) of dimethiodide, m.p. 205–206.5°. The analytical sample was prepared by recrystallization of this material from 75% ethanol; white powder, m.p. 212° dec.

Anal. Calcd. for $C_{14}H_{28}I_2N_2$: C, 35.16; H, 5.90; N, 5.86. Found: C, 34.85; H, 5.91; N, 5.52.

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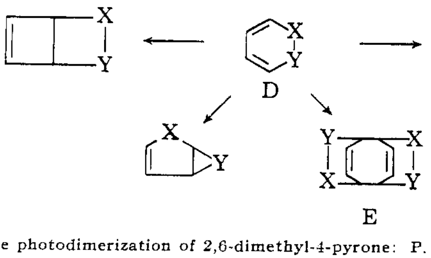
[36] After completion of this work, a report that 2-aminopyridine hydrochloride also photodimerizes to give 4,8-diimino-3,7-diazatricyclo$[4.2.2.2^{2,5}]$-dodeca-9,11-diene dihydrochloride has appeared,[16] and indicates that new synthetic possibilities do indeed exist.

[37] In this regard, the cage structure (a) has been demonstrated to result from the photodimerization of 2,6-dimethyl-4-pyrone: P. Yates and M. J. Jorgenson, *J. Am. Chem. Soc.*, **80**, 6150 (1958).



[38] All melting points were uncorrected. Infrared and ultraviolet data were in agreement in all cases. Magnesium sulfate was used throughout as the drying agent where applicable.

[39] Florisil is a magnesia–silica gel adsorbent manufactured by the Floridin Co., Tallahassee, Fla.

[40] In the case of XVIII, water was used as solvent; XIV was reduced in acetic acid at 100°; this was necessitated because of the insolubility of XIV in the usual organic solvents at lower temperatures.