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PHOTO-OXIDATION OF INDOLE DERIVATIVES

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Abstract—The UV irradiation of 2- and 3-methylindoles in acetic acid leads to the formation of the corresponding indole-carboxaldehydes as the major products, whereas the employment of ethanol as solvent causes the cleavage of the C_2-C_3 bond, giving *o*-acylaminophenylketones.

Some aspects of these photo-reactions are discussed.

We have reported that by means of a photo-oxidation reaction it is possible to convert a Me group into an aldehyde group when the Me group is attached to the indazole ring. This reaction was applied to different 1-(*p*-nitrophenyl)-methylindazoles and several 1-(*p*-nitrophenyl)-formylindazoles were thus prepared.[1,2]

This photochemical method was considered to be of preparative value and the previous results prompted us to study the possibilities of this photo-oxidation when Me derivatives of other heterocyclic compounds are employed.

In spite of the interest shown in indole derivatives (Discussion), the effect of UV light on such substances has not been systematically studied. We now report our findings on UV irradiation of indole compounds.[3]

When a solution of 2,3-dimethyl-5-nitroindole in acetic acid was irradiated, a product was obtained in 43% yield (**7**, Table 1). The IR spectrum of this product showed a CO absorption at 1640 cm^{-1} and its NMR spectrum indicated that one Me group of the original compound had been transformed into an aldehyde group. To demonstrate that the indole structure was present in the product, the aldehyde **7** was reduced with sodium borohydride to the corresponding hydroxymethyl derivative (**28**) whose UV spectrum was almost identical to that of the original indole. On the other hand, the hydroxymethyl compound **28** was reconverted into the aldehyde **7** by UV irradiation.

The same photo-reaction was then applied to the other 2,3-dimethyl-nitroindole isomers, giving in all cases the corresponding indole-aldehydes (**6**, **8** and **9**).

By irradiation of 2,3-dimethylindole we obtained an aldehyde which was identified as 3-methylindole-2-carboxaldehyde (**1**). This compound was previously prepared by other methods.[4,5] In order to prove that in the cases of the 2,3-dimethylnitroindoles the Me group involved in the oxidation was that located at position 2, we treated the 3-methylindole-2-carboxaldehyde (**1**), dissolved in acetic acid, with conc nitric acid. The nitration mixture was resolved by preparative TLC giving the four nitroindole-2-carboxaldehydes which were identified with the products (**6**–**9**) already mentioned (Scheme 1).

This photochemical process was then extended to other 2-methylindoles; the aldehydes obtained (**1**–**15**) are listed in Table 1, whereas the corre-

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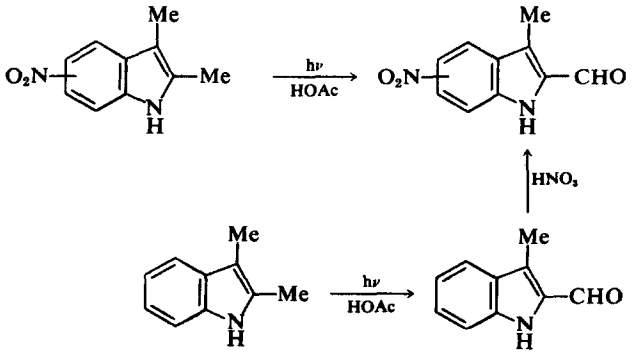
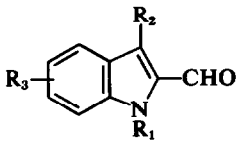


SCHEME 1

Table 1. Indole-2-carboxaldehydes obtained by UV irradiation of 2-methylindoles in acetic acid solution



	R_1	R_2	R_3	m.p.	irrad. time (h)	conv. %	yield %	Formula	Analysis Required/Found C	H	N	λ_{max} nm (log ϵ) solvent, EtOH
1	H	Me	H	139–40°[a]	1	60	17	$C_{10}H_9NO$		Ref. 4		237 (4·09); 314 (4·32)
2	H	Ph	H	194–97°[b]	2	82	40	$C_{15}H_{11}NO$		Ref. 8		228 (4·28); 249 (4·42); 319 (4·38)
3	H	Me	5-Me	186–89°[c]	2	80	18	$C_{11}H_{11}NO$	76·27 76·03	6·40 6·29	8·09 8·24	239 (4·22); 318 (4·44)
4	H	Ph	5-Me	204–06°[b]	2	92	41	$C_{16}H_{13}NO$	81·68 81·47	5·57 5·76	5·95 6·20	230 (4·30); 249 (4·33); 322 (4·38)
5	H	H	5-NO_2	246–47°[b]	4	94	10	$C_9H_6N_2O_3$	56·84 57·02	3·18 3·45	14·73 14·66	288 (4·58); 318 sh (4·08)
6	H	Me	4-NO_2	225°[b] (d)	8	80	2	$C_{10}H_8N_2O_3$	58·82 58·75	3·95 4·26	13·72 14·00	233 (4·19); 337 (3·89)
7	H	Me	5-NO_2	290°[b] (d)	4	97	43	$C_{10}H_8N_2O_3$	58·82 58·70	3·95 4·11	13·72 13·91	296 (4·59); 335 sh (4·06)
8	H	Me	6-NO_2	254–56°[b]	2·5	88	30	$C_{10}H_8N_2O_3$	58·82 58·65	3·95 3·98	13·72 13·77	240 (4·04); 255 (4·02); 330 (4·26); 370 sh (3·64)
9	H	Me	7-NO_2	158–60°[b]	9	97	48	$C_{10}H_8N_2O_3$	58·82 58·36	3·95 4·08	13·72 13·95	298 (4·18); 372 (4·11)
10	Me	Me	5-NO_2	220–22°[b]	2	90	41	$C_{11}H_{10}N_2O_3$	60·54 60·39	4·62 4·90	12·84 12·82	298 (4·66); 335 sh (4·08)
11	H	Ph	5-NO_2	273–74°[b]	5	87	51	$C_{15}H_{10}N_2O_3$	67·66 67·61	3·79 3·95	10·52 10·67	237 (4·19); 245 sh (4·19); 299 (4·50); 331 sh (4·04)
12	H	Ph	6-NO_2	250–52°[b]	6	100	33	$C_{15}H_{10}N_2O_3$	67·66 67·45	3·79 3·93	10·52 10·76	234 (4·29); 244 sh (4·24); 300 (4·28); 329 (4·30)
13*	H	Ph	7-NO_2	168–70°[b]	20	90	55	$C_{15}H_{10}N_2O_3$	67·66 67·76	3·79 4·07	10·52 10·52	242 (4·61); 270 sh (4·07); 306 (4·04); 376 (4·17)
14†	H	Me	5-Cl	230°[b] (d)	2	97	17	$C_{10}H_8ClNO$[e]	62·01 61·94	4·16 4·00	7·23 7·32	240 (4·28); 315 (4·39)
15	H	Ph	5-Cl	240–42°[b]	2	80	47	$C_{15}H_{10}ClNO$		Ref. 8		249 (4·42); 318 (4·31)

*From the irradiation of 2-methyl-3-phenyl-7-nitroindole, **34** was obtained together with the aldehyde **13** (Experimental).

†In this case a little (4%) of the corresponding acetophenone (Ref 9) was also obtained.

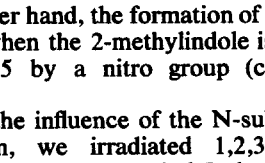
Recrystallization solvents: [a]ligroin; [b]EtOH; [c]EtOH–H_2O. [e]Chlorine determination: Required, 18·31. Found, 18·41.

sponding NMR data are given in Table 4.

The structures of the aldehydes **3**, **4**, **10** and **14**, which derived from di- and trimethylindoles, were determined by correlation of their NMR data with those of the starting indoles (Table 6) and by comparison of the UV spectra with those of appropriate indole-2-carboxaldehydes (**3** with **1**; **4** with **2**; **10** with **7**; **14** with **1**).

These results indicate that the Me group at position 2 is preferably oxidized when it competes with other Me groups located at positions 1, 3 or 5. Besides, this preference is independent of the type and position of other substituents, but the influence of the position of substituents such as the nitro group, is shown on the yields obtained (Table 1).

2-Methylindole is an exception to the phototransformation R—CH_3 → R—CHO. By irradiation we obtained, instead of the corresponding aldehyde, the dimer **29**, a substance which was previously prepared by other oxidative methods.[6,7]



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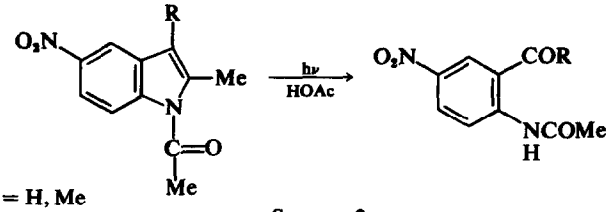
On the other hand, the formation of the aldehyde is possible when the 2-methylindole is substituted at position 5 by a nitro group (compound **5**, Table 1.)

To study the influence of the N-substitution on this reaction, we irradiated 1,2,3-trimethyl-5-nitroindole, 1-acetyl-2-methyl-5-nitroindole and 1-acetyl-2,3-dimethyl-5-nitroindole. While the former substrate afforded the corresponding indole-2-carboxaldehyde (**10**), a different photo-oxidation occurred in the case of the N-acetyl derivatives which produced the cleavage of the C_2—C_3 bond

giving, as major products, the 2-acetamido-5-nitrobenzaldehyde (30) and the 2-acetamido-5-nitroacetophenone (24) respectively (Scheme 2).

Also, from the photo-reaction of the 2-phenyl-3-methyl-6-nitroindole the aldehyde 19 and the corresponding nitroacetophenone (32) were



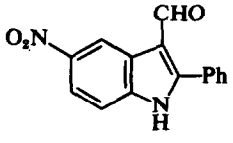
SCHEME 2

The photo-conversion of a Me group into an aldehyde group is also possible when the Me group is attached to the position 3 of the indole ring. The indole-3-carboxaldehydes (16–21) prepared by this photochemical method are given in Table 2 and their NMR data are in Table 5.

In some cases the photo-oxidations are more complex than previously described and together with the aldehydes other products are formed. For example, from the UV irradiation of the 2-phenyl-3-methyl-5-nitroindole three products were obtained: 2-phenyl-5-nitroindole-3-carboxaldehyde (18), 2-benzamido-5-nitroacetophenone (25) and 2-phenyl-6-nitro-4H-[3,1]-benzoxazin-4-one (31).

isolated, whereas the reaction of the 2-phenyl-3-methyl-7-nitroindole afforded the aldehyde 20 together with the 2-phenyl-3-hydroxymethyl-7-nitroindole (33). It should be mentioned that the 2-phenyl-3-methyl-4-nitroindole was recovered unchanged after 20 hr irradiation.

We have also observed that the course of the photo-oxidation depends on the solvent employed. Thus, the UV irradiation of 2-Me-, 3-Me- and 2,3-dimethylindoles in ethanol solution produces an oxidative cleavage and gives *o*-acylaminophenylketones instead of the aldehydes formed when the same photo-reactions were performed employing acetic acid as solvent. The phenylketones prepared by this way are included in Table 3.



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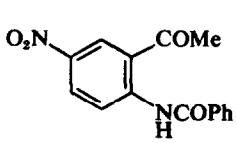

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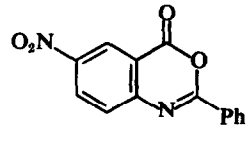

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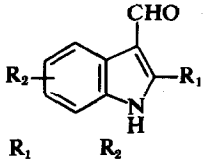
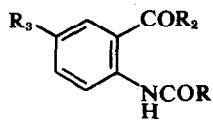
Table 2. Indole-3-carboxaldehydes obtained by UV irradiation of 3-methylindoles in acetic acid solution



	R_1	R_2	m.p.	irrad. time (h)	conv. %	yield %	Formula	Analysis Required/Found C	H	N	λ_{max} nm (log ε) solvent, EtOH
16	Ph	H	253–55°[a]	2	75	35	$C_{15}H_{11}NO$		Ref. 10		257 (4·46); 314 (4·15)
17	Ph	5-Me	269–71°[a]	2	90	38	$C_{16}H_{13}NO$		Ref. 11		224 (4·40); 261 (4·52); 318 (4·26)
18*	Ph	5-NO_2	330°[b] (d)	4	100	18	$C_{15}H_{10}N_2O_3$	67·66 67·76	3·79 3·95	10·52 10·62	263 (5·46); 285 sh (4·33); 326 sh (4·11)
19*	Ph	6-NO_2	320°[b] (d)	3	100	42	$C_{15}H_{10}N_2O_3$	67·66 67·61	3·79 4·05	10·52 10·25	285 (4·39); 326 (4·17)
20*	Ph	7-NO_2	278–80°[b]	27	88	21	$C_{15}H_{10}N_2O_3$	67·66 67·53	3·79 4·08	10·52 10·76	242 (4·42); 288 sh (3·90); 346 (4·10)
21	Ph	5-Cl	295–97°[a]	3	73	26	$C_{15}H_{10}ClNO$[c]	70·46 70·79	3·94 3·67	5·48 5·75	225 (4·41); 259 (4·56); 312 (4·28)

*Other products obtained in these irradiations are described in Experimental.
Recrystallization solvents: [a]EtOH; [b]acetic acid. [c]Chlorine determination: Required, 13·87. Found, 14·16.

Table 3. *o*-Acylaminophenylketones obtained by UV irradiation of methylindoles in ethanol solution



	R_1	R_2	R_3	m.p.	irrad. time (h)	conv. %	yield %	Literature m.p.	NMR data (δ values) solvent, DMSO-d_6
22	Ph	Me	H	96–97°[a]	7	100	57	Ref. 12, 98°	CH_3 2·68; arom. prot. 7·10–8·20 (8H); H_3 8·66 (*dd*, $J_{3,5}$ 1 c/s; $J_{3,4}$ 8 c/s); NH 12·36
23	Ph	Me	Me	120–22°[a]	6	100	50	Ref. 13, 120°	5-CH_3 2·36; CH_3CO 2·70; arom. prot. 7·38–8·08 (7H); H_3 8·58 (*d*, $J_{3,4}$ 9 c/s); NH 12·30
24	Me	Me	NO_2	152–54°[b]	9	93	22	Ref. 14, 152–53°	$NCOCH_3$ 2·18; $COCH_3$ 2·70; H_3 and H_4 8·38; H_6 8·63; NH 11·33
25	Ph	Me	NO_2	194–95°[b]	10	87	42	Ref. 15, 194–95°	CH_3 2·76; C_6H_5 7·46–8·10; H_4 8·46 (*dd*, $J_{4,6}$ 2·5 c/s; $J_{3,4}$ 9 c/s); H_6 8·75 (*d*, $J_{4,6}$ 2·5 c/s); H_3 8·80 (*d*, $J_{3,4}$ 9 c/s); NH 12·45
26	Me	Ph	NO_2	157–59°[b]	9	86	47	Ref. 15, 159°	CH_3 1·86; C_6H_5 7·40–7·80; H_3 7·80 (*d*, $J_{3,4}$ 9 c/s); H_6 8·08 (*d*, $J_{4,6}$ 2·5 c/s); H_4 8·36 (*dd*, $J_{4,6}$ 2·5 c/s; $J_{3,4}$ 9 c/s); NH 10·46
27	Ph	Me	Cl	140–42°[b]	5	95	17	Ref. 16, 140–41·5°	CH_3 2·70; H_4 and C_6H_5 7·50–8·06; H_6 8·11 (*d*, $J_{4,6}$ 3 c/s); H_3 8·63 (*d*, $J_{3,4}$ 9 c/s); NH 12·16

Recrystallization solvents: [a]EtOH–H_2O; [b]EtOH.

DISCUSSION

The photochemical method here applied to the synthesis of indole-carboxaldehydes constitutes a new procedure for the oxidation of a Me group attached to positions 2 or 3 of the indole leaving the heterocyclic ring intact.

There are few cases in the indole series in which oxidizing agents cause the selective oxidation of alkyl substituents.[26] For example, the 2,3-dimethylindole was transformed into 3-methylindole-2-carboxaldehyde by treatment with periodic acid[5] (yield 10%) and the 3,4,6-trinitro-2-methylindole was oxidized to the corresponding indole-2-carboxylic acid employing sodium permanganate.[27] Most of the oxidizing agents produce an oxidative dimerization, the oxidation of the indole ring to form glycols, or more frequently, the oxidative cleavage of the C_2—C_3 bond giving *o*-acylaminophenylketones or N-acylanthranilic acids.[26] Besides, some indole derivatives react with oxygen, in an autoxidative process, to form 3-hydroperoxyindolenines[28] as isolable primary products.

In several cases, the hydroperoxides give a subsequent reaction and products of different type are formed. In a chemiluminescent reaction the 3-hydroperoxyindolenines are transformed, in the presence of bases, into *o*-acylaminophenylketones.[9] These products are also formed by thermal decomposition of the hydroperoxides in neutral[28] or acid media.[17]

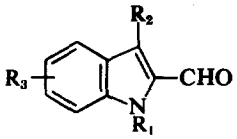
On the other hand, the autoxidation of 2,3-dimethylindole afforded *o*-acetamidoacetophenone together with a small amount of 3-methylindole-2-carboxaldehyde.[29] There are other examples in which the autoxidation involves an alkyl substituent attached to the position 2 of the indole ring.[30]

These results indicate that 3-hydroperoxyindolenines could be formed during the UV irradiation of indoles in the first step of the reaction sequence which leads to the formation of indolealdehydes. To study this possibility we prepared three 3-hydroperoxyindolenines (**36**, **37** and **39**) which were submitted to thermal and photochemical decomposition in acetic acid solution. The results of these transformations are compared, in Table 7, with those obtained from the irradiation of the parent indole in acetic acid or ethanol solution.

The data indicate that 3-hydroperoxyindolenines are not intermediates in the formation of aldehydes, because the products distribution obtained from the irradiation of the indoles in acetic acid and the thermal or photochemical decomposition of the hydroperoxides, are different.

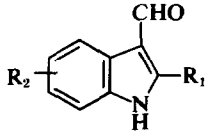
Robertson[28] has mentioned that among the structural features which inhibit or prevent the formation of 3-hydroperoxyindolenines are: the N-substitution, the presence of strongly electron attracting groups in the benzene ring and the presence of a Ph group in the 3-position. In connection with this, we irradiated the 2-methyl-3-phenyl-nitroindoles obtaining the corresponding aldehydes as sole products and in good yields (Table 1). These results agree with our suggestion that the 3-hydroperoxyindolenines are not inter-

Table 4. NMR spectra of indole-2-carboxaldehydes (δ values; solvent DMSO-d_6)



	R_1	R_2	R_3	CH_3	Aromatic protons	CHO	NH
1	H	Me	H	2·60	6·85–7·81	10·01	11·50
2	H	Ph	H		7·13–8·00	10·01	12·31
3	H	Me	5-Me	2·53 (3) 2·36 (5)	H_4 7·41; H_6 7·06 (*dd*, $J_{4,6}$ 2 c/s; $J_{6,7}$ 9 c/s); H_7 7·28 (*d*, $J_{6,7}$ 9 c/s)	9·95	11·35
4	H	Ph	5-Me	2·45	H_6 7·40 (*dd*, $J_{4,6}$ 1 c/s; $J_{6,7}$ 9 c/s); H_4, H_7 and C_6H_5 7·56–7·91	10·05	12·26
5	H	H	5-NO_2		H_3 7·71; H_4 8·83 (*d*, $J_{4,6}$ 2 c/s); H_6 8·21 (*dd*, $J_{4,6}$ 2 c/s; $J_{6,7}$ 9 c/s); H_7 7·63 (*d*, $J_{6,7}$ 9 c/s)	9·98	12·58
6	H	Me	4-NO_2	2·58	7·00–7·91	10·20	12·33
7	H	Me	5-NO_2	2·65	H_4 8·65 (*d*, $J_{4,6}$ 2 c/s); H_6 8·08 (*dd*, $J_{4,6}$ 2 c/s; $J_{6,7}$ 9 c/s); H_7 7·46 (*d*, $J_{6,7}$ 9 c/s)	10·03	12·15
8	H	Me	6-NO_2	2·60	H_4 and H_5 7·85 (*d*, *J* 1 c/s); H_7 8·20 (*t*, *J* 1 c/s)	10·08	12·15
9	H	Me	7-NO_2	2·60	H_4 8·20 (*dd*, $J_{4,6}$ 1 c/s; $J_{4,5}$ 8 c/s); H_5 7·26 (*t*, *J* 8 c/s); H_6 8·26 (*dd*, $J_{4,6}$ 1 c/s; $J_{5,6}$ 8 c/s)	10·20	11·76
10	Me	Me	5-NO_2	4·06 (1) 2·70 (3)	H_4 8·73 (*d*, $J_{4,6}$ 2 c/s); H_6 8·30 (*dd*, $J_{4,6}$ 2 c/s; $J_{6,7}$ 9 c/s); H_7 7·80 (*d*, $J_{6,7}$ 9 c/s)	10·20	
11	H	Ph	5-NO_2		H_4 8·51 (*d*, $J_{4,6}$ 2 c/s); H_6 8·18 (*dd*, $J_{4,6}$ 2 c/s; $J_{6,7}$ 9 c/s); H_7 and C_6H_5 7·40–7·75	9·81	12·66
12	H	Ph	6-NO_2		H_4 and H_5 7·96; H_7 8·40; C_6H_5 7·43–7·86	10·03	12·86
13	H	Ph	7-NO_2		H_4 8·16 (*d*, *J* 8 c/s); H_5 7·38 (*t*, *J* 8 c/s); H_6 8·36 (*dd*, $J_{4,6}$ 1 c/s; $J_{5,6}$ 8 c/s); C_6H_5 7·45–7·80	9·96	11·70
14	H	Me	5-Cl	2·55	H_4 7·73; H_6 and H_7 7·26–7·40	10·01	11·70
15	H	Ph	5-Cl		7·20–7·68	9·75	12·18

Table 5. NMR spectra of indole-3-carboxaldehydes (δ values; solvent DMSO-d_6)



	R_1	R_2	CH_3	Aromatic protons	CHO	NH
16	Ph	H		H_4 8·15–8·46 (m); H_5, H_6, H_7 and C_6H_5 7·16–8·10	10·11	12·50
17	Ph	5-Me	2·46	H_4 8·18; H_6 7·20 (*d*, $J_{6,7}$ 9 c/s); H_7 and C_6H_5 7·40–8·01	10·11	12·45
18	Ph	5-NO_2		H_4 9·05 (*d*, $J_{4,6}$ 2 c/s); H_6 8·20 (*dd*, $J_{4,6}$ 2 c/s; $J_{6,7}$ 9 c/s); H_7 and C_6H_5 7·50–8·00	10·05	13·03
19	Ph	6-NO_2		7·41–8·40	9·96	12·90
20	Ph	7-NO_2		H_4 8·61; H_5 and C_6H_5 7·26–7·86; H_6 8·16	9·90	12·50
21	Ph	5-Cl		H_4 8·15 (*d*, $J_{4,6}$ 2 c/s); H_6 7·23 (*dd*, $J_{4,6}$ 2 c/s; $J_{6,7}$ 9 c/s); H_7 and C_6H_5 7·38–7·88	9·90	12·48

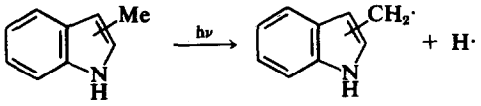
mediates in the photochemical formation of indole-aldehydes.

It was recently reported[31] the photo-transformation of an Et group into an acetyl group in 2-ethyl-3,3-disubstituted indolenines, substances which could not form 3-hydroperoxyindolenines.

On the other hand, the 2-phenyl-3-methyl-3-hydroperoxyindolenines (**36** and **39**) are photochemically decomposed to a mixture of the acetophenone and the corresponding indole-3-carboxaldehyde, whereas the thermal reaction afforded only the acetophenone. In these cases the photochemical formation of the aldehyde could be due to a migration of the hydroperoxide group to the Me group or to the decomposition of the hydroperoxide into the original 3-methylindole and its subsequent photo-oxidation. The thermal migration of the 3-hydroperoxide group to a Me group located at position 2 had been suggested.[29] From the data given in Table 7 we can conclude that the light has no effect on this transformation.

On the basis of these observations we can postul-

ate that the photo-oxidation of methylindoles in acetic acid begins as follows:



a

The radical *a* could then react with oxygen to form an hydroperoxide radical R—$CH_2OO\cdot$ which abstracts an H atom of another molecule giving the hydroperoxide R—CH_2OOH. These hydroperoxides could then be transformed into aldehydes. The formation of similar hydroperoxides and its decomposition was previously postulated by us studying the photo-oxidation of methylindazoles.[1,2]

Although the formation of hydroperoxides R—CH_2OOH seems to be predominant, we can not exclude the simultaneous formation, in a lesser extent, of 3-hydroperoxyindolenines, or the cyclic peroxides, because these intermediate substances could be responsible for the side reactions observed (Scheme 3).

It is interesting to note that these side reactions are important only in the cases in which the formation of 3-hydroperoxyindolenines is not strongly inhibited by the structural features already mentioned.

As postulated, the photo-oxidation of methylindoles must follow a radical mechanism because when the reactions were performed in the presence of radical trapping agents the reactions were inhibited.

To study the effect of other oxidizing agents on methylindoles we submitted some of the indoles used for the photochemical reactions, to oxidation with peracetic acid, because it resembles the photochemical system, and with $NaOCl–H_2O_2$, mixture which generates singlet oxygen.[32] From these reactions products derived from the cleavage of the $C_2—C_3$ bond of the indole and a 3-hydroxyindolenine (**40**) were isolated.

Irradiations of methylindoles in ethanol solution follow a different course producing the rupture of the pyrrole ring with formation of *o*-acylaminophenylketones in good yields. In these cases aldehydes were present in a very small amount and were detected by TLC.

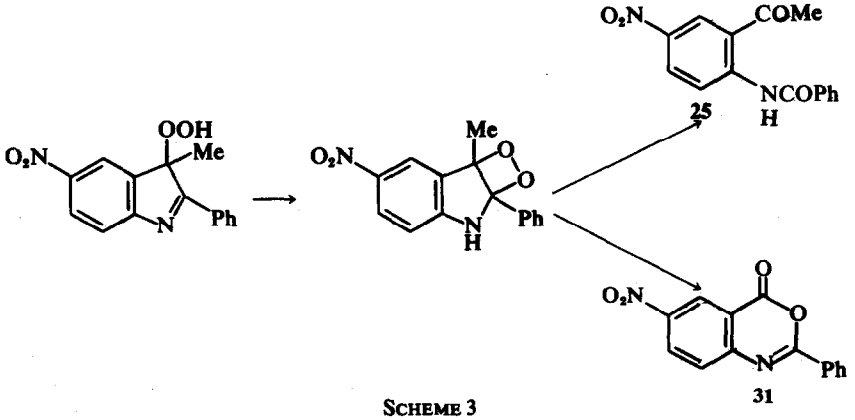
Now, the predominant radical must be *b* and this radical in the subsequent step forms 3-hydroperoxyindolenines (Scheme 4) which decompose to *o*-acylaminophenylketones. These photo-reactions are inhibited by 2,6-di-t-butylphenol.

These findings let us assume that in all cases both radicals (*a* and *b*) are in competition and that the course of the photo-oxidation depends on the stabilities of both radicals in the solvent employed.

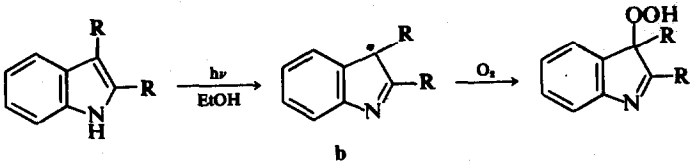
The formation of products derived from the cleavage of the $C_2—C_3$ bond obtained by UV irradiation of N-acetylindoles in acetic acid could be explained considering that the primary effect of the light can be the homolytic fission of the N—CO bond yielding a radical which is stabilized as *b*.

EXPERIMENTAL

M.ps are uncorrected. The UV spectra were determined on a Beckman DK-2A spectrophotometer. The NMR spectra were recorded on a Varian A-60 spectrometer using TMS as internal standard.



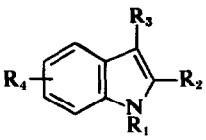
SCHEME 3



b

SCHEME 4

Table 6. NMR spectra of the indole derivatives used for the photochemical reactions* (δ values; solvent DMSO d_6)

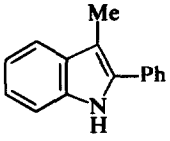
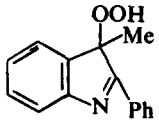
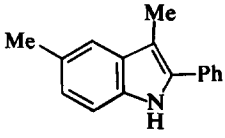
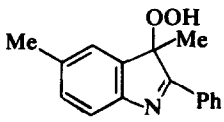
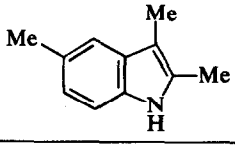
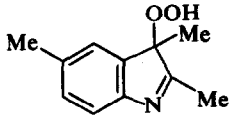


R_1	R_2	R_3	R_4	CH_3	Aromatic protons	NH	Ref.
H	Me	H	H	2·38	H_3 6·12; 6·86–7·48 (4H)	10·86	18
H	Me	Me	H	2·13 (3) 2·28 (2)	6·78–7·45	10·50	18
H	Me	Ph	H	2·51	7·06–7·83	11·33	19
H	Ph	Me	H	2·41	6·95–7·78	11·08	18
H	Me	Me	5-Me	2·10 (3) 2·26 (2) 2·33 (5)	H_4 7·06; H_6 6·71 (dd, $J_{4,6}$ 2 c/s; $J_{6,7}$ 8 c/s); H_7 7·05 (d, $J_{6,7}$ 8 c/s)	10·38	20
H	Me	Ph	5-Me	2·38 (5) 2·48 (2)	H_6 6·98 (dd, $J_{4,6}$ 1 c/s; $J_{6,7}$ 9 c/s); 7·28–7·65 (7H)	11·16	19
H	Ph	Me	5-Me	2·41 (3 and 5)	H_6 7·01 (dd, $J_{4,6}$ 1 c/s; $J_{6,7}$ 9 c/s); 7·26–7·90 (7H)	11·10	13
H	Me	H	5-NO_2	2·46	H_3 6·46; H_4 8·45 (d, $J_{4,6}$ 2 c/s); H_6 7·98 (dd, $J_{4,6}$ 2 c/s; $J_{6,7}$ 8 c/s); H_7 7·46 (d, $J_{6,7}$ 8 c/s)	11·60	21
H	Me	Me	4-NO_2	2·18 (3) 2·40 (2)	H_6 6·96–7·28; H_5 and H_7 7·50–7·74	11·56	22
H	Me	Me	5-NO_2	2·20 (3) 2·35 (2)	H_4 8·30 (d, $J_{4,6}$ 2 c/s); H_6 7·88 (dd, $J_{4,6}$ 2 c/s; $J_{6,7}$ 9 c/s); H_7 7·33 (d, $J_{6,7}$ 9 c/s)	11·41	22
H	Me	Me	6-NO_2	2·20 (3) 2·40 (2)	H_4 7·45 (d, $J_{4,5}$ 9 c/s); H_5 7·81 (dd, $J_{5,7}$ 2 c/s; $J_{4,5}$ 9 c/s); H_7 8·13 (d, $J_{5,7}$ 2 c/s)	11·46	22
H	Me	Me	7-NO_2	2·20 (3) 2·41 (2)	H_4 7·86 (d, J 8 c/s); H_5 7·13 (t, J 8 c/s); H_6 8·00 (d, J 8 c/s)	11·45	22
H	Me	Ph	5-NO_2	2·55	H_4 8·41 (d, $J_{4,6}$ 2 c/s); H_6 8·02 (dd, $J_{4,6}$ 2 c/s; $J_{6,7}$ 9 c/s); H_7 and C_6H_5 7·40–7·63	12·00	15
H	Me	Ph	6-NO_2	2·53	H_4 7·53 (d, $J_{4,5}$ 9 c/s); H_5 7·86 (dd, $J_{5,7}$ 2 c/s; $J_{4,5}$ 9 c/s); H_7 8·21 (d, $J_{5,7}$ 2 c/s); C_6H_5 7·41	11·91	23
H	Me	Ph	7-NO_2	2·55	H_4 7·90 (d, J 8 c/s); H_5 7·16 (t, J 8 c/s); H_6 8·03 (d, J 8 c/s); C_6H_5 7·45	11·85	24
H	Ph	Me	5-NO_2	2·50	H_4 8·53 (d, $J_{4,6}$ 2 c/s); H_6 8·06 (dd, $J_{4,6}$ 2 c/s; $J_{6,7}$ 9 c/s); H_7 and C_6H_5 7·40–7·86	11·96	15
H	Ph	Me	6-NO_2	2·41	H_4 and C_6H_5 7·31–7·70; H_5 7·86 (dd, $J_{5,7}$ 2 c/s; $J_{4,5}$ 9 c/s); H_7 8·18 (d, $J_{5,7}$ 2 c/s)	11·86	23
H	Ph	Me	7-NO_2	2·38	H_4 7·96 (d, J 8 c/s); H_5 7·16 (t, J 8 c/s); H_6 8·01 (d, J 8 c/s); C_6H_5 7·28–7·80	11·36	23
H	Me	Me	5-Cl	2·10 (3) 2·26 (2)	H_4 7·30 (d, $J_{4,6}$ 2 c/s); H_6 6·86 (dd, $J_{4,6}$ 2 c/s; $J_{6,7}$ 9 c/s); H_7 7·16 (d, $J_{6,7}$ 9 c/s)	10·73	20
H	Me	Ph	5-Cl	2·45	H_4, H_7 and C_6H_5 7·21–7·50; H_6 7·00 (dd, $J_{4,6}$ 2 c/s; $J_{6,7}$ 9 c/s)	11·28	—
H	Ph	Me	5-Cl	2·36	H_4, H_7 and C_6H_5 7·20–7·75; H_6 7·01 (dd, $J_{4,6}$ 2 c/s; $J_{6,7}$ 9 c/s)	11·25	—
Me	Me	Me	5-NO_2	2·26 (3) 2·36 (2) 3·70 (1)	H_4 8·40 (d, $J_{4,6}$ 2 c/s); H_6 7·99 (dd, $J_{4,6}$ 2 c/s; $J_{6,7}$ 9 c/s); H_7 7·50 (d, $J_{6,7}$ 9 c/s)		25
Ac	Me	H	5-NO_2	2·70 (2) 2·78 (1)	H_3 6·73; H_4 8·40 (d, $J_{4,6}$ 2 c/s); H_6 8·03 (dd, $J_{4,6}$ 2 c/s; $J_{6,7}$ 9 c/s); H_7 8·30 (d, $J_{6,7}$ 9 c/s)		21
Ac	Me	Me	5-NO_2	2·16 (3) 2·51 (2) 2·70 (1)	7·80–8·23		15

*The assignments of 2-CH_3 and 3-CH_3 in the cases of 2,3-dimethylindoles were established by correlation of our data with those reported by Dave and Warnhoff (ref 17) for the 2-methyl-3-methyl-d_3-indole.

General method of irradiation. The indoles (30 mg) were irradiated in HOAc solns (15 ml) placed in Pyrex test tubes (16 × 150 mm). The light source was a Hg high-pressure lamp (Philips 400 watts) which was placed 11·5 cm from the tubes. The solns reached a maximal temp of 50° after 15 min irradiation. Irradiations times are given in Tables 1 and 2; the progress of the reaction was followed by TLC (silica gel; benzene or benzene-EtOH). The soln was then diluted with water and the product extracted with benzene or $CHCl_3$. The organic layer was separated and washed with water and then with $NaHCO_3$ aq. The residue obtained by evaporation of the solvent was chromatographed on alumina. Benzene or mixtures of benzene-EtOH were used as eluents. In all

Table 7

Products obtained from the UV irradiation of indoles in HOAc and EtOH solutions	solv.	ald. %	acetoph. %	Thermal and photochemical decomposition of 3-hydroperoxyindolenines in HOAc		ald. %	acetoph. %
	HOAc	35	—		hν	4	40
	EtOH	—	57		Δ	—	47
	HOAc	38	—		hν	3	38
	EtOH	—	50		Δ	—	64
	HOAc	18	—		hν	15	22
	EtOH	2	21		Δ	16	21

cases, the first eluted fraction contained the non-converted starting indole, whereas the photoproducts eluted in the following order: first the aceto- or benzophenones and then the indole-carboxaldehydes. Other products obtained are specially indicated in each case.

Irradiations in EtOH were performed in a similar manner (Table 3). EtOH was evaporated and the residue was chromatographed on a silica gel column.

The bands on the columns and the spots on the TLC plates were made visible by UV light. The aldehydes were revealed by spraying the plates with an alcoholic soln of 2,4-dinitrophenylhydrazine acidified with H_2SO_4.

Preparation of the indole compounds used for the photochemical reactions

The indole derivatives employed in this work were prepared according to methods described (Table 6), except in the cases indicated below.

2-Methyl-3-phenyl-5-chloroindole. The phenylacetone *p*-chlorophenylhydrazone (3 g) was dissolved in EtOH previously saturated with HCl (30 ml) and the mixture was heated under reflux for 4 hr. After dilution with water the product was extracted with benzene. The solvent was evaporated and the residue, dissolved in ligroin, was chromatographed on a silica gel column. The indole compound was obtained from the first eluted fraction (825 mg). Colourless plates from EtOH—H_2O, m.p. 86–88°. (Found: C, 74·30; H, 5·00; N, 5·71; Cl, 14·80. $C_{15}H_{12}NCl$ requires: C, 74·52; H, 5·00; N, 5·80; Cl, 14·66%); UV (EtOH) λ_{max} 299 sh nm (log ϵ 4·00); 274 (4·23); 229 (4·59).

2-Phenyl-3-methyl-5-chloroindole. It was prepared in a similar way by cyclization of the propiophenone *p*-chlorophenylhydrazone, colourless prisms from EtOH—H_2O (yield 47%), m.p. 128–30°. (Found: C, 74·30; H, 5·17; N, 5·82; Cl 14·59. $C_{15}H_{12}NCl$ requires: C, 74·52; H, 5·00; N, 5·80; Cl, 14·66%); UV (EtOH) λ_{max} 313 nm (log ϵ 4·33); 235 (4·44).

Acetophenones and benzophenones obtained in this work. Samples of substances reported in the literature were used to identify the photoproducts, and were prepared by oxidation of the corresponding indoles with chromic acid.

Irradiation of 2-methylindole

Formation of **29**. The 2-methylindole (210 mg) was dissolved in HOAc (105 ml) and the soln was irradiated for 1 hr. The product was extracted with $CHCl_3$ and the residue obtained by evaporation of the solvent was chromatographed on alumina (eluent, benzene). From the first fraction the non-converted starting indole (98 mg) was obtained whereas the product from the second fraction was identified as **29** (60 mg, yield 13%), yellow needles from benzene, m.p. 198–200° (lit.[7] m.p. 212°); UV (EtOH) λ_{max} 405 nm (log ϵ 3·54); 288 sh (3·97); 280 (4·02); 259 (4·16); NMR (DMSO-d_6) 2-CH_3 1·76; 2′-CH_3 2·41; arom. prot. and 1-NH 6·60–7·80 (9H); 1′-NH 10·86.

Irradiation of 1-acetyl-2-methyl-5-nitroindole

Formation of **30**. A soln of 1-acetyl-2-methyl-5-nitroindole (210 mg) in HOAc (105 ml) was irradiated for 2·5 hr. The column chromatography (silica gel, benzene) of the product yielded 2-methyl-5-nitroindole and 1-acetyl-2-methyl-5-nitroindole in the first fraction. From the second fraction **30** (25 mg, yield 12%) was obtained as colourless plates from EtOH, m.p. 156–58° (lit.[33] m.p. 160–61°); NMR (DMSO-d_6) $COCH_3$ 2·23; H_3 and H_4 8·43; H_6 8·71; CHO 10·05; NH 11·08. A little (5 mg) of **5** was obtained from the third fraction.

Irradiation of 1-acetyl-2,3-dimethyl-5-nitroindole

Formation of **7** *and* **24**. The title compound (180 mg) was irradiated in HOAc (90 ml) for 6 hr. Chromatography of the mixture gave the following results: 2,3-dimethyl-5-nitroindole (19 mg); **24** (42 mg, yield 23%) and **7** (12 mg, yield 7%).

Irradiation of 2-methyl-3-phenyl-7-nitroindole

Formation of **13** *and* **34**. The non-converted starting indole and the aldehyde **13** (Table 1) were isolated from the first and second fraction in chromatography of the mixture. From the third fraction (eluent, benzene-EtOH 99·5:0·5) **34** (yield 22%) was obtained as orange needles from EtOH—H_2O, m.p. 162–65° (d). (Found: C, 67·38; H, 4·08; N, 10·38. $C_{15}H_{12}N_2O_3$ requires: C, 67·15; H, 4·51; N, 10·44%); UV (EtOH) λ_{max} 365 nm (log ϵ 3·96); 258 (4·19); NMR (DMSO-d_6) CH_2 4·68; (*d*, *J* 5·5 c/s); OH 5·30 (*t*, *J* 5·5 c/s); H_5 7·20 (*t*, *J* 8 c/s); C_6H_5 7·25–7·60; H_4 7·98 (*d*, *J* 8 c/s); H_6 8·10 (*d*, *J* 8 c/s); NH 11·63.

The same compound was obtained by reduction of **13** with $NaBH_4$ in EtOH soln at room temp.

Irradiation of 2-phenyl-3-methyl-5-nitroindole

Formation of **18**, **25** *and* **31**. The indole was dissolved in HOAc and after irradiation the soln was left at room temp for 12 hr and **18** was filtered off (this compound is described in Table 2). The filtrate was diluted with water and extracted with benzene. The residue obtained by evaporation of the solvent was chromatographed on a silica gel column (eluent, benzene-EtOH 99·8:0·2). From the first fraction a product was identified as **31** (yield 12%); pale yellow needles from EtOH, m.p. 170–74°. (Found: C, 62·81; H, 2·85; N, 10·26. $C_{14}H_8N_2O_4$ requires: C, 62·69; H, 3·01; N, 10·45%); UV (EtOH) λ_{max} 337 nm (log ϵ 4·46); 245 sh (4·28); 226 (4·40); NMR ($CDCl_3$) $H_{3'}$, $H_{4'}$ and $H_{5'}$ 7·33–7·71; H_8 7·81 (*d*, $J_{7,8}$ 9 c/s); $H_{2'}$ and $H_{6'}$ 8·08–8·43; H_7 8·61 (*dd*, $J_{5,7}$ 2·5 c/s; $J_{7,8}$ 9 c/s); H_5 9·05 (*d*, $J_{5,7}$ 2·5 c/s).

The second fraction was eluted with a mixture of benzene-EtOH (99·5:0·5) giving after evaporation, **25** (yield 27%), which is described in Table 3.

Irradiation of 2-phenyl-3-methyl-6-nitroindole

Formation of **19** *and* **32**. The irradiation was performed as described. The mixture was diluted with water and **19** was filtered off. The filtrate was extracted with $CHCl_3$ and the residue obtained by evaporation of the solvent was recrystallized from EtOH giving a further amount of **19** which was combined with the previous batch. The aldehyde **19** is described in Table 2.

The mother liquors after recrystallization of **19** were evaporated and the residue, dissolved in benzene, was chromatographed on alumina (eluent, benzene); **32** (yield 5%) was obtained from the first fraction as pale yellow needles from EtOH, m.p. 160–63° (lit[23] m.p. 160–61°); NMR (DMSO-d_6) CH_3 2·71; H_5 and C_6H_5 7·48–8·06; H_6 8·25 (*d*, $J_{5,6}$ 9 c/s); H_3 9·20 (*d*, $J_{3,5}$ 2 c/s); NH 12·00.

Irradiation of 2-phenyl-3-methyl-7-nitroindole

Formation of **20** *and* **33**. Chromatography of the mixture yielded the starting material, the aldehyde **20** (Table 2) and a third compound identified as **33** (yield 8%) but which gave no satisfactory micro-analysis results was obtained as yellow needles from EtOH—H_2O, m.p. 205° (*d*); UV (EtOH) λ_{max} 363 nm (log ϵ 4·13); 273 sh (4·32); NMR (DMSO-d_6) CH_2 4·75 (*d*, *J* 5 c/s); OH 5·16 (*t*, *J* 5 c/s); H_5 7·38 (*t*, *J* 8 c/s); C_6H_5 7·45–8·08; H_4 8·23 (*d*, *J* 8 c/s); H_6 8·28 (*d*, *J* 8 c/s); NH 11·75.

Nitration of 3-methylindole-2-carboxaldehyde (**1**)

Formation of compds. **6**, **7**, **8** *and* **9**. Compound **1** (42 mg) was dissolved in HOAc (5 ml) and to the soln conc HNO_3 (1 ml; δ 1·5) was slowly added. The reaction progress was monitored by TLC and after 45 min (room temp) the soln was diluted with water and extracted with benzene. TLC of the nitration product (silica gel; benzene-EtOH 98·5:1·5) showed the presence of the four nitro-3-methylindole-2-carboxaldehydes isomers, the 4-nitro- and the 6-nitro derivatives being the principal products. To eliminate impurities the mixture was chromatographed on a silica gel column using benzene as eluent. The principal fraction (second) was a mixture of the four nitroindole-2-carboxaldehydes. These were then isolated by repeated preparative TLC (alumina; benzene-EtOH 99·6:0·4) and identified with the corresponding compounds obtained by the photochemical method. The R_f order on the alumina plate was as follows: **1**, **9**; **2**, **6**; **3**, **8** and **4**, **7**.

Preparation of 2-hydroxymethyl-3-methyl-5-nitroindole (**28**) *by reduction of the aldehyde* (**7**). Aldehyde **7** (59 mg) was dissolved in a soln of EtOH—H_2O and at room temp $NaBH_4$ was slowly added. The reaction progress was followed by TLC and when the aldehyde disappeared the addition of $NaBH_4$ was stopped. The EtOH was evaporated and the product was extracted with $CHCl_3$. Yellow prisms from benzene (37 mg, yield 62%), m.p. 193–94°. (Found: C, 58·37; H, 4·94; N, 13·63. $C_{10}H_{10}N_2O_3$ requires: C, 58·25; H, 4·89; N, 13·58%); UV (EtOH) λ_{max} 334 nm (log ϵ 3·94); 275 (4·31); 260 sh (4·27); NMR (DMSO-d_6) CH_3 2·28; CH_2 4·66 (*d*, *J* 5 c/s); OH 5·30 (*t*, *J* 5 c/s); H_7 7·43 (*d*, $J_{6,7}$ 9 c/s); H_6 7·96 (*dd*, $J_{4,6}$ 2 c/s; $J_{6,7}$ 9 c/s); H_4 8·41 (*d*, $J_{4,6}$ 2 c/s); NH 11·63.

Irradiation of **28**. A soln of **28** (24 mg) in HOAc (12 ml) was irradiated for 1·5 hr. The soln was extracted with $CHCl_3$ and the residue obtained by evaporation of the solvent, was recrystallized from EtOH and identified as **7** (18 mg, yield 75%).

Preparation of 2-hydroxymethyl-3-methyl-7-nitroindole (**35**) *by reduction of the aldehyde* **9**. The reaction was conducted as in the previous case. Yellow prisms from benzene (yield 95%), m.p. 133–34°. (Found: C, 58·06; H, 4·85; N, 13·60. $C_{10}H_{10}N_2O_3$ requires: C, 58·25; H, 4·89; N, 13·58%); UV (EtOH) λ_{max} 371 nm (log ϵ 3·86); 257 (4·02); 238 (4·11); NMR (DMSO-d_6) CH_3 2·26; CH_2 4·66; OH 5·05; H_5 7·13 (*t*, *J* 8 c/s); H_4 7·90 (*d*, *J* 8 c/s); H_6 8·01 (*d*, *J* 8 c/s); NH 11·21.

2-Phenyl-3-methylindolenyl-3-hydroperoxide (**36**). This compound was prepared according to a known method.[28] Colourless prisms from EtOAc-ligroin, m.p. 145° (*d*) (lit.[34] m.p. 154–56°; lit.[13] m.p. 164°); NMR (DMSO-d_6) CH_3 1·56; arom. prot. 7·36–7·83 (7H); $H_{2'}$ and $H_{8'}$ 8·30–8·53; OOH 12·05.

Thermal decomposition of **36** *in acetic acid.* The hydroperoxide **36** (80 mg) was dissolved in HOAc (40 ml) and the soln was heated in the dark at 60° for 3 hr. Compound **22** (Table 3) was isolated by chromatography on silica gel (38 mg, yield 47%) as the sole product.

In another experiment **36** (18 mg) was dissolved in CD_3COOD (0·5 ml) and the soln was placed in NMR tube. NMR (CD_3COOD) CH_3 1·61; arom. prot. 7·36–7·95 (7H); $H_{2'}$ and $H_{8'}$ 8·36–8·61. The NMR tube was heated in a water bath at 80° for 3 hr. After that time, the NMR spectrum obtained showed that all the original hydroperoxide had been transformed into **22**.

Photochemical decomposition of **36** *in acetic acid.* A soln of **36** (60 mg) in HOAc (30 ml) was irradiated for 1 hr (reaction temp 50°). The mixture was chromatographed on an alumina column (eluent, benzene) giving from the first fraction **22** (24 mg, yield 40%), whereas

from the second fraction 16 (3 mg, yield 4%) was obtained.

2,3,5-*Trimethylindolenyl*-3-*hydroperoxide* (37). It was prepared as described by Sugiyama *et al.*[9] as colourless prisms from EtOAc-ligroin, m.p. 108–11° (lit.[9] m.p. 111·5°); NMR (DMSO-d_6) 3-CH_3 1·36; 2-CH_3 2·25; 5-CH_3 2·38; arom. prot. 7·25–7·50 (3H); OOH 11·88.

Thermal decomposition of 37 *in acetic acid.* A soln of 37 (90 mg) in HOAc (45 ml) was heated in the dark at 60° for 2 hr. The mixture was extracted with benzene and the residue obtained by evaporation of the solvent was chromatographed on alumina (eluent, benzene). Compound[9] 38 (19 mg, yield 21%) was obtained from the first fraction; NMR (DMSO-d_6) $NCOCH_3$ 2·13; 5-CH_3 2·36; $COCH_3$ 2·65; H_4 7·55 (*dd*, $J_{4,6}$ 1 c/s; $J_{3,4}$ 9 c/s); H_6 7·93 (*d*, $J_{4,6}$ 1 c/s); H_3 8·33 (*d*, $J_{3,4}$ 9 c/s); NH 11·26.

The residue obtained from the second fraction was identified as 3 (13 mg, yield 16%).

Photochemical decomposition of 37 *in acetic acid.* The hydroperoxide 37 (50 mg) dissolved in HOAc (25 ml) was irradiated for 1 hr. The isolation of the products was achieved as in the previous case: 38 (11 mg, yield 22%); 3 (7 mg, yield 15%).

2-*Phenyl*-3,5-*dimethylindolenyl*-3-*hydroperoxide* (39). This compound was prepared according to a known method[28] as colourless needles from EtOAc-ligroin, m.p. 125–27° (lit.[13] m.p. 168°); NMR (DMSO-d_6) 3-CH_3 1·51; 5-CH_3 2·40; arom. prot. 7·10–7·70 (6H); $H_{2'}$ and $H_{6'}$ 8·15–8·40; OOH 11·83.

Thermal decomposition of 39 *in acetic acid.* This reaction was conducted as in other cases and gave as unique product 23 (yield 64%). When this decomposition was carried out in CD_3COOD and the progress of the reaction was monitored by NMR, an almost quantitative transformation of 39 into the corresponding acetophenone was observed.

Photochemical decomposition of 39 *in acetic acid.* A soln of 39 (60 mg) in HOAc (30 ml) was irradiated for 2 hr. The mixture was chromatographed on alumina (eluent, benzene) giving from the first fraction 23 (23 mg, yield 38%), whereas from the second fraction 17 (2 mg, yield 3%) was obtained.

The effect of phenols on the UV irradiation of indoles. A. 2-Methyl-3-phenyl-5-nitroindole (50·4 mg) and 2,6-di-t-butylphenol (4·12 mg) were dissolved in HOAc (25 ml) and the soln was irradiated for 5 hr. By chromatography of the mixture the starting indole (47 mg) was recovered.

B. 2-Phenyl-3-methyl-5-nitroindole (25·2 mg) and 2,6-di-t-butyl-*p*-cresol (11·0 mg) were dissolved in HOAc and the soln was irradiated for 4 hr. The original indole (25 mg) was recovered as above.

C. 2-Methyl-3-phenyl-5-nitroindole (76·5 mg) and 2,6-di-t-butylphenol (6·18 mg) were dissolved in EtOH (32·5 ml) and the soln was irradiated for 9 hr. The starting indole (54 mg) was recovered as in the other cases.

Oxidations with peracetic acid

A. The 2-methyl-3-phenyl-5-nitroindole (60 mg) was dissolved in a 0·04 M soln of H_2O_2 in HOAc (30 ml) and the mixture was left at room temp for 20 hr. The soln was then diluted with water and extracted with benzene. The product obtained by evaporation of the solvent was identified as 26 (63 mg, yield 94%).

B. The oxidation of the 2-phenyl-3-methyl-5-nitroindole (30 mg) was conducted as in the previous case (reaction time: 3 hr) giving 25 (33 mg, yield 99%).

Oxidations with NaOCl—H_2O_2

A. The 2-methyl-3-phenyl-5-nitroindole (50·4 mg) was dissolved in a 0·2 M soln of H_2O_2 in EtOH (6 ml). To this soln was then dropwise added a 0·66 M aq soln of NaOCl (2 ml). The mixture was left at room temp for 4 hr and then diluted with water and extracted with benzene. The extracts were concentrated and chromatographed on a silica gel column allowing the isolation of the following fractions:

First: Non-transformed starting indole (15 mg); *Second:* 2-Amino-5-nitrobenzophenone (8 mg, yield 16%); yellow prisms from EtOH—H_2O, m.p. 161–63° (lit.[15] m.p. 163·5°); NMR (DMSO-d_6) H_3 7·01 (*d*, $J_{3,4}$ 9 c/s); C_6H_5CO 7·66 (5H); H_4, H_6 and NH_2 8·05–8·33; *Third:* 26 (15 mg, yield 26%).

B. The oxidation of the 2-phenyl-3-methyl-5-chloroindole (80 mg) was performed as in the previous case. By chromatography on alumina the following products were isolated:

First: Non-converted indole (2 mg); *Second:* 27 (44 mg, yield 48%); *Third:* 40 (21 mg, yield 24%) as colourless needles from benzene-ligroin, m.p. 183–84°. (Found: C, 69·82; H, 4·96; N, 5·65; Cl 13·96. $C_{15}H_{12}ClNO$ requires: C, 69·89; H, 4·70; N, 5·44; Cl, 13·76%); UV (EtOH) λ_{max} 320 nm (log ϵ 4·24); 248 sh (4·17); 241 (4·22); 233 sh (4·21); NMR (DMSO-d_6) CH_3 1·56; OH 6·36; arom. prot. 7·28–7·73 (6H); $H_{2'}$ and $H_{6'}$ 8·21–8·48.

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