

# Photoreactions of 2-Amino-2-Phenylindan-1,3-Dione Derivatives\*

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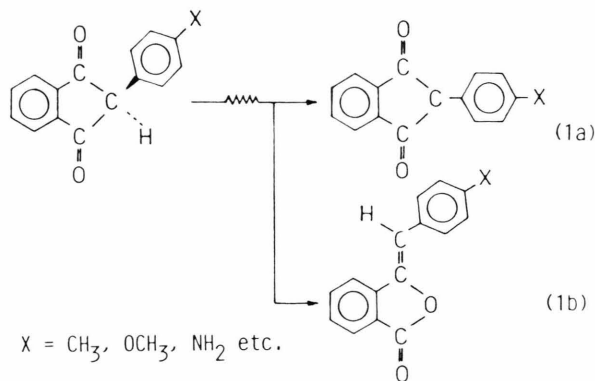
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The photochemical behaviour of several derivatives of 2-amino-2-phenylindan-1,3-dione, substituted in the amino group was investigated by means of steady state irradiation and flash photolysis. It is shown, that two photoisomerization reactions take place simultaneously: i) photoisomerization to 3-aminosubstituted-benzylidene-phthalides; ii) photoisomerization to 2-substituted-3-phenyl-isoquinolinones. Both processes result from a bond rupture according to a Norrish type I reaction mechanism.

## 1. Introduction

Derivatives of 2-phenylindan-1,3-dione (ID) have been shown to undergo two different primary photo-reactions:

- Formation of the corresponding indandion-2-yl free radicals of which the spectra and reactions have been studied previously [1–6].
- A photoisomerization to the corresponding 3-phenyl-methylene-1 (3H)-isobenzofuranones (ben-



\* Dedicated to Prof. Dr. Nikolay Tyutyulkov on the occasion of his 60th birthday.

\*\* Reprint request to Prof. Dr. N. Getoff, Institut für Theoretische Chemie und Strahlenchemie, Universität Wien, Währingerstr. 38, A-1090 Wien, Austria.

zylidenephthalides, BPh), most likely due to a Norrish type I process [1, 2, 7, 8].

The yield of this isomerization process, which has also found preparative interest [9], depends on the substituents in the studied compounds and on the solvent. The yields are highest in solvents as cyclohexane, where the diketone form predominates, which is to be expected for the Norrish type I splitting assumed as the primary step. The biradical thus formed rearranges to the BPh via a rotation of a C-C-bond. For preparative purposes it is of great interest to know, whether other derivatives might lead to ring closure reactions others than those to isobenzofuranones. Various investigations have shown the occurrence of base catalyzed isomerization reactions of amino-ketones [10] as well as of derivatives of indan-1,3-dione in the ground state [11, 12]. In most cases they lead to the formation of products which belong to different classes of chemical compounds: Indole [13, 15], naphthalene [11] and isoquinolinone [16, 17]. Recently, the base catalyzed isomerization of derivatives of 2-amino-ID (I), substituted at the amino group, has been described in various organic solvents (ethanol, acetone, dioxane, dimethylformamide) at elevated temperatures [18]. Depending on the duration of the treatment and on the concentration of the nucleophilic catalyst, either 3-amino-BPh (II) or 2-substituted 1,4-dioxo-3-phenyl-1, 2, 3, 4-tetrahydro-

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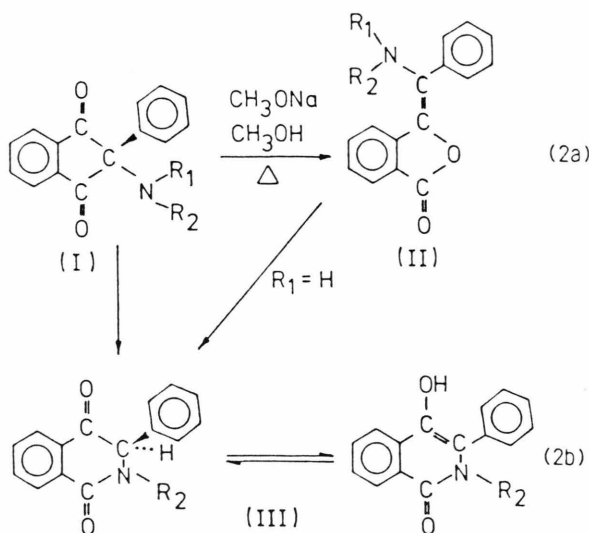
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isoquinolines (IQ, III) were observed as final products:



The derivatives of ID can exist in three tautomeric forms depending on the solvent polarity [19]. The diketo-form, which predominates in nonpolar solvents, the enol form, prevailing in polar protic solvents and the anion-form, which can be formed in water at  $\text{pH} \geq 12$ .

A detailed investigation of the mechanism of photochemical rearrangement of these three tautomeric forms, coupled with PPP-SCF-CI and CNDO/S-quantum chemical calculations [20], showed that the diketo tautomeric form of indan-diones is responsible for their photoisomerization to benzylidene-phthalides.

The aim of the present study was, therefore, to test the occurrence of photochemical pendants on the base catalyzed IQ-derivatives from 2-amino-ID-derivatives. Such a reaction should be of preparative interest, particularly with compounds which are unstable in alkaline solution. Further, ID and its derivatives are acting as antioxidants for various polymers, e.g. polypropylene [21]. In addition to this indantrion and similar compounds can be used as sensitizers for the treatment of cancer cells [22].

## 2. Experiments

The investigated derivatives of 2-amino-ID (see Table 1) were synthesized according to the method by Wanag and Walbe [23]. The products were repeatedly recrystallized from glacial acetic acid until a constant

melting point was obtained. Their purity was furthermore controlled by thin layer chromatography.

Derivatives of BPh as well as of IQ were synthesized for reference purposes using the method by Arens and Lencbergs [18]. The solvents were of reagent grade and redistilled before use. In order to avoid the formation of dimers as has been observed with similar compounds [24], the concentration of the substrate was kept below  $10^{-5} \text{ mol dm}^{-3}$ .

The flash photolysis experiments were performed independently with two instruments (Applied Photo-physics, London, Flash Kinetic Spectrophotometer KN 100 and modified "Northern Precision" apparatus (half life time of the flash,  $t/2 = 6 \mu\text{s}$ ) as described elsewhere [1].

Steady state photochemical experiments were carried out with a medium pressure mercury lamp (Tungsum HGO 125 W) using 1 cm quartz cells. If not otherwise stated the period of the irradiations amounted 90 min at a distance of 20 cm in air saturated solutions.

Fluorescence spectra were recorded by means of a spectrofluorimeter (Perkin Elmer MPF 44 B), whereas the absorption spectra were recorded with a Specord M40 (Carl Zeiss, Jena) or on a Hitachi 115-20 spectrophotometer. For the measurements of IR-spectra a Perkin-Elmer 257 instrument was used. In addition NMR-spectra were also obtained by means of a "TESLA 487 C" (80 MHz) as well as with a "Jeol C-60 S" (60 MHz) spectrometer. The results obtained with both instruments were nearly identical.

## 3. Results

### 3.1. Flash photolysis

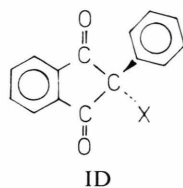
The transient obtained from 2-amino-ID in ethanol showed a strong absorption band at 400 nm. The resulting final product has absorption maxima at 325 and 400 nm (Figure 1).

No transients were observed by flashing derivatives of 2-benzyl-amino-ID and of 2-dimethylamino-ID using dichloroethane as solvent.

The spectra of the stable products resulting from 2-benzyl-amino-ID and of 2-dimethylamino-ID, both in ethanol are presented in Fig. 2 and 3 respectively.

The absorption and fluorescence data of 3-amino-substituted-BPh derivatives and of 2-substituted-IQ derivatives are compiled in Table 1.

Table 1. Absorption and fluorescence characteristics of the final photochemical products obtained from substituted 2-amino-ID (column A) as well as of reference compounds (column B). – Photoproduct II: 3-aminosubstituted-BPh and photoproduct III: 2-substituted-IQ (see Eqs. 2a and 2b).



No.	X	Photoproduct:							
		II				III			
		$\lambda_{\text{abs}}$ (nm)		$\lambda_{\text{F}}$ (nm)		$\lambda_{\text{abs}}$ (nm)		$\lambda_{\text{F}}$ (nm)	
		A	B	A	B	A	B	A	B
1	–NH <sub>2</sub>	325 385	324 384	460	460	320	304	435	435
2	–NHCH <sub>2</sub> C <sub>6</sub> H <sub>5</sub>	325 385	322 385	465	465	308	310	450	450
3	–NHC <sub>2</sub> H <sub>5</sub>	330 395	326 395	470	470	310	307	455	455
4	–N< $\begin{smallmatrix} \text{CH}_3 \\ \text{CH}_3 \end{smallmatrix}$	355 400	336 398	470	460	–	–	–	–
5	–N< $\begin{smallmatrix} \text{CH}_2\text{CH}_2 \\ \text{CH}_2\text{CH}_2 \end{smallmatrix}$ >CH <sub>2</sub>	330 395	328 395	470	470	–	–	–	–

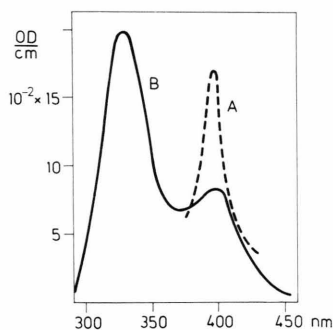


Fig. 1. Transient absorption spectrum (A) obtained by flash photolysis of airfree  $5 \times 10^{-5} \text{ mol dm}^{-3}$  2-amino-ID in ethanol (50  $\mu\text{s}$  after flash; discharge voltage: 12.5 kV). (B) Spectrum of a final product observed 0.8 ms after flash. (Absorption bands at: 325 and 400 nm.)

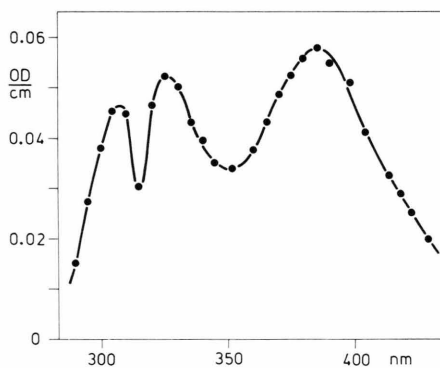


Fig. 2. Total absorption spectrum of stable products formed upon flash photolysis of  $5 \times 10^{-4} \text{ dm}^{-3}$  2-benzylamino-ID in ethanol. Discharge voltage: 12.5 kV; OD measurement: 50 ms after flash.

### 3.2. Steady state experiments

#### Absorption and Fluorescence Spectroscopy

Figure 4 shows the absorption spectrum of 2-benzylamino-ID in ethanol. In the insert the differential spectrum after 10 min irradiation with a mer-

cury lamp is given (spectrum B) together with absorption spectrum of 3-benzylamino-BPh (spectrum A) and the absorption spectrum of 2-benzyl-IQ (spectrum C) in ethanol. The comparison of the absorption spectra shows that the absorption bands of the photoproducts and of 3-benzylamino-BPh and of 2-benzyl-IQ synthesised according to [18], are identical in position (see also Table 1).

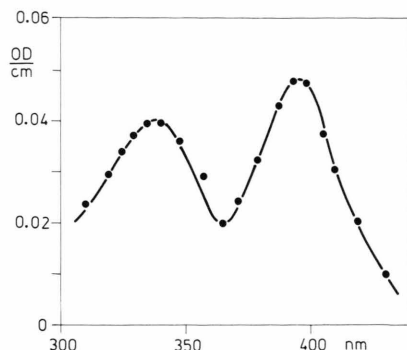


Fig. 3. Absorption spectrum of the stable products formed by flash photolysis of  $5 \times 10^{-4} \text{ mol dm}^{-3}$  2-dimethylamino-ID in ethanol. Discharge voltage: 12,5 kV. OD-values measured 50 ms after flash.

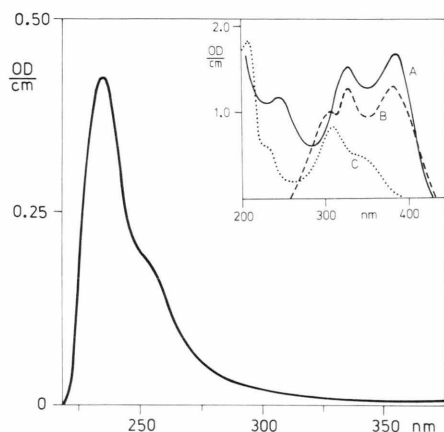


Fig. 4. Absorption spectrum of  $1 \times 10^{-5} \text{ mol dm}^{-3}$  2-benzylamino-ID in ethanol. *Insert:* (A) Absorption spectrum of  $5 \times 10^{-5} \text{ mol dm}^{-3}$  3-benzylamino-BPh in ethanol. (B) Differential absorption spectrum of 2-benzylamino-ID in ethanol, irradiated for 10 min with medium pressure mercury lamp (see text). (C) Absorption spectrum of  $5 \times 10^{-5} \text{ mol dm}^{-3}$  2-benzyl-ID in ethanol.

The luminescence characteristics, particularly of benzylidene-phthalides and isoquinolinones has not yet been described in the literature. The fluorescence properties of the photoproducts were, therefore, compared with those of reference compounds as mentioned above. Based on their rather close similarity, one can assume that the photoproducts most probably correspond to 3-benzylamino-BPh and 2-benzyl-IQ, respectively (see Table 1 and Fig. 5).

The formation of the IQ-derivative was also observed both photochemically and in a dark reaction from 3-benzylamino-BPh, but its formation rate is much slower.

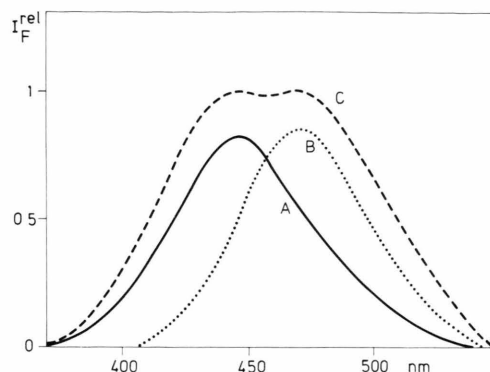


Fig. 5. Fluorescence spectra ( $I_F^{\text{rel}}$  as function on nm) in ethanol of: (A)  $10^{-5} \text{ mol dm}^{-3}$  2-benzyl-IQ, (B)  $10^{-5} \text{ mol dm}^{-3}$  3-benzylamino-BPh and (C)  $10^{-5} \text{ mol dm}^{-3}$  2-benzylamino-ID, irradiated for 10 min with a medium pressure mercury lamp.

### Thin Layer Chromatography

Thin layer chromatography experiments of 2-benzylamino-ID in dichloroethane (n-hexane:acetone = 40:10; Merck Kieselgel 40 without fluorescence indicator) showed the formation of both, 3-benzylamino-BPh and of 2-benzyl-IQ. Most likely the separation of different tautomeric forms of the isoquinolinone is possible. Further, spots were observed, but they were not yet fully identified.

### Isolation of the Products of Photoisomerization of 2-benzylamino-ID

For this purpose the following procedure was applied: 0.200 g ( $6.1 \times 10^{-4}$  moles) 2-benzylamino-ID were dissolved in 40 ml ethanol. The solution was irradiated in a quartz vessel with a medium pressure mercury lamp (Tungsram HGO 125 W) for 9 min. The solution was evaporated to 5 ml, and was passed through Kieselgel 40 with ethylacetate:ether = 1:4 as an eluent. 0.105 g of 3-benzylamino-BPh and 0.086 g of 2-benzyl-IQ were obtained. The products of isomerization were characterized by IR, NMR, UV-VIS absorption and fluorescence spectra. The obtained data are for: a) 3-benzylamino-BPh  $\lambda_{\text{abs}}$  (EtOH): 325 nm, 385 nm;  $\lambda_{\text{fl}}$  (EtOH): 465 nm; IR (KBr):  $\lambda_{\text{max}}$  at  $3380 \text{ cm}^{-1}$ ,  $1745 \text{ cm}^{-1}$ ,  $1640 \text{ cm}^{-1}$ ;  $^1\text{H-NMR}$  ( $\text{D}_2\text{O}$ ) ppm: 4.14 ( $\text{CH}_2$ ), 5.17 (NH). b) 2-benzyl-IQ:  $\lambda_{\text{abs}}$  (EtOH) 308 nm;  $\lambda_{\text{fl}}$  (EtOH) 450 nm; IR (KBr):  $\lambda_{\text{max}}$  at  $3200 \text{ cm}^{-1}$ ,  $1650 \text{ cm}^{-1}$ ,  $1618 \text{ cm}^{-1}$ ,  $1580 \text{ cm}^{-1}$ ;  $^1\text{H-NMR}$  ( $\text{D}_2\text{O}$ ) ppm: 4.31 (OH), 5.13 ( $\text{NCH}_2\text{C}_6\text{H}_5$ ).

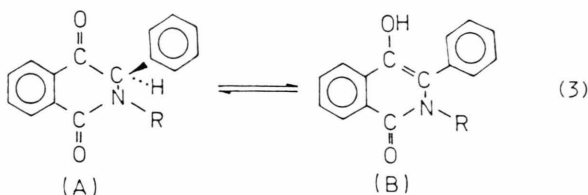
#### 4. Discussion

The experimental results show, that the flash photolysis, as well as the photolysis at steady state conditions of derivatives of 2-amino-ID, monosubstituted in the amino group, lead to the simultaneous formation of two final products: 3-amino-substituted-BPh and 2-substituted-IQ-derivatives. The formation of both BPh and IQ takes place with the resolution time of the Flash photolysis apparatus (ca. 2  $\mu$ s). The nature of the observed transients (Fig. 1) is not yet clear. They are definitely not precursors of neither BPh nor IQ; they are tentatively assigned to N-radicals because of:

- Their absence in solvents which do not favour the splitting of H-atoms and
- also of their absence in the case of 2-benzyl-amino-ID and 2-dimethylamino-ID derivative.

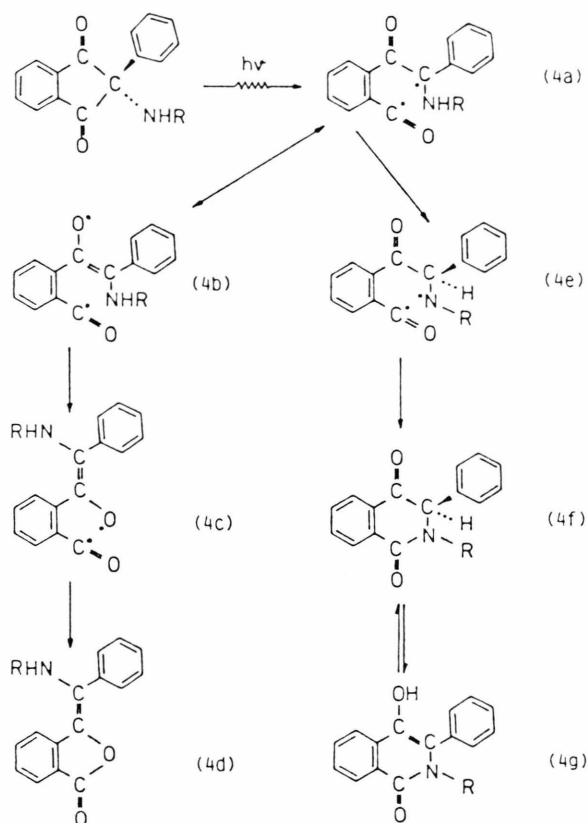
These transients most likely are the precursors of byproducts, which have not been yet identified.

It is well known, that IQ-derivatives lines can exist in different tautomeric forms, depending on the solvent polarity [18]. The experimental results (IR- and NMR-spectra of the isolated product) show, that the photochemical rearrangement of the starting indandiones in ethanol (isomer A) leads to the formation of the enol form of the corresponding isoquinolinone (isomer B).



In the case when the amino group is disubstituted, the photoreaction leads to the formation of only one product, namely the corresponding isobenzofuranone. This fact could be explained assuming the following mechanism of the photochemical isomerization, which includes the direct participation of a H-atom of the amino-group.

As with other indandione derivatives, the primary step follows the pattern of a Norrish-type-I-reaction. The use of nonpolar aprotic solvents like cyclohexane



or n-heptane, which are known to favour such reactions in similar cases [1, 2, 7, 8, 24], was excluded for solubility reasons. The results show, however, that in the case of 2-amino-ID derivatives, isomerization pathways constitute the main reaction route even in solvents like ethanol.

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