Photocyclyzation of 2-azidobenzophenone

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Abstract:

During the thermolysis of 2-azidobenzophenone an azide group due to 1,3-dipolar cyclization reacts with carbonyl group without an intermediate formation of nitrene. The reaction gives high yields of 3-phenylanthranil.

Photolysis of 2-azidobenzophenone as well as other aromatic azides gives singlet nitrenes as decomposition products. Small singlet-triplet gap wikens triplet forbiddance partly and transition from the singlet into the triplet state becames possible by means of intersystem crossing. Thus, two high reactivity intermediates form under photolysis of the azide. It determines the subsequent reactions. The singlet nitrene can insert into carbonyl group giving 3-phenylanthranil, and the triplete nitrene can dimerise to form azocompound or abstract an hydrogen atom from solvent to form amines.

We have found that the 2-azidobenzophenone photolysis in acetonitrile gives high yields of 3-phenylanthranil. The scheme becomes complicated by the 3-phenylanthranil secondary decomposition. No azocompound was found. We have proposed that there has place transition of nitrene into a low reactive conjugated biradical having electron density localized on nitrogen atom of nitrene and oxygen atom of carbonyl group. The biradical gives 3-phenylanthranil by means of intersystem crossing into the singlet state.

Keywords: 2-azidobenzophenone, 3-phenylanthranyl, aromatic azide photochemistry, photolysis, nitrene

Introduction: Thermal, catalytic, and photochemical lability of azide group gives us a possibility to use aromatic azides as reagents to form nitrogen – carbon and nitrogen – heteroatom bonds.

Today, catalysis by transitional metal salts is the most actively developed direction in heterocycles synthesis [1]. However, in the reactions with substrates that can easily coordinate with such salts (with biopolymers, for instance) their introduction into the reaction media turns into irreversible sorption. Biopolymers can loose their biological activity in such circumstances.

The shortcoming is absent in photochemical reactions, when we have an ability to choose proper wavelength of actinic irradiation. However, the formation of radicals and other intermediates in the excited state complicates the photolysis mechanism and decrease the yield of the desirable product. That is why a search of optimal ways to form the concrete product in the photochemical reactions is very important.

In this paper we described our preliminary results of the 2-asidobenzophenone photolysis in acetonitrile.

Experimental Procedure

General information

2-asidobenzophenone synthesis

2.66 g (0.0135 mole) of 2-asidobenzophenone, 15 ml of conc. HCl, and 5 ml of water were place into a glass with volume of 200 ml. The mixture was stirred up to formation of gray homogeneous suspention. After that the reaction mixture was cooled and solution of 1.05 g of $NaNO_2$ in 10 ml of water was added dropwise into the glass under constant stirring. The precipitate obtained was dissolved to give yellow-brown solution, that was hold in ace for 40 min. That time the solution became brown and precipitate was formed. The diazonium salt was filtered, and 2.69 g of NaN_3 was added into reaction media under constant stirring. After that the reaction media was hold in dark for 12 hours.

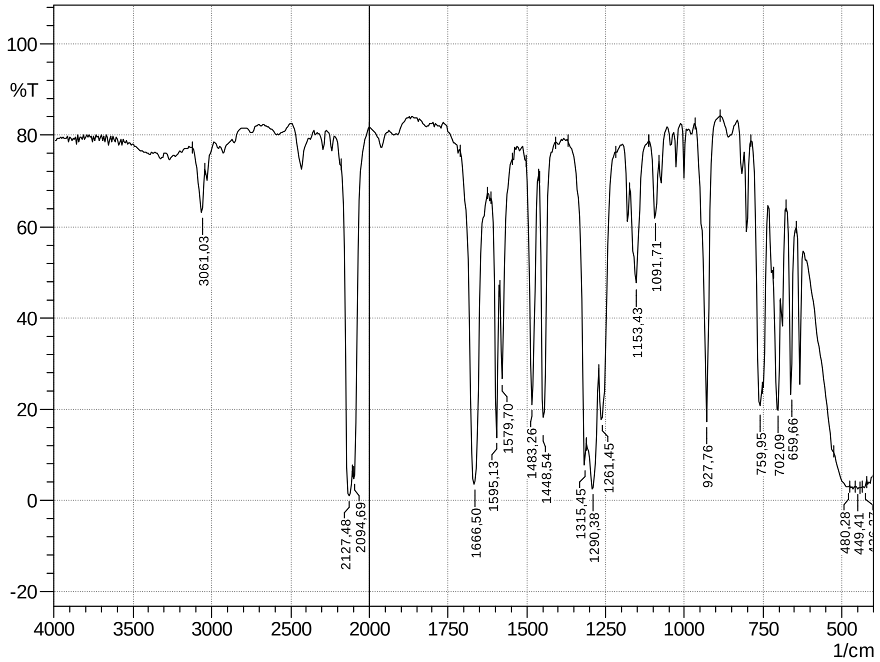


Fig.1. IR spectra of 2-asidobenzophenone in nuiol.

The solution decame transparent with dark oil on the bottom. Azide was extracted 3 times using 30 ml and 2 times using 10 ml of CH_2Cl_2. Extract was dried above calcined Na_2SO_4, after that the solvent was removed in vacuo. 2-asidobenzophenone was purified with preparative colomn chromatography using silica gel and heptane-CH_2Cl_2 (1:1, v/v) as an eluent. After purification the azide became light-yellow. IR spectrum of the azide is shown on Fig. 1.

Synthesis of 3-phenylanthranyl. 0.157 g of 2-azidobenzophenone was boiled in 5 ml of o-cresol (b.p.=144 ^{o}C) in 30 min. This time is sufficient for complete decomposition of azide (observed due to decrease of the azidogroup asymmetric stretching vibration). The color of the solution changes from yellowish to saturated yellow. The solvent was removed under heating in vacuo. The isolated crystals were thrice recrystalized from ethanol (1-2 ml) with separation of filtered products under the solvent cooling below -19 ^{o}C. Mass-spectrum was measured and it was in closed coincidence with known from literature [2] (Fig.2).

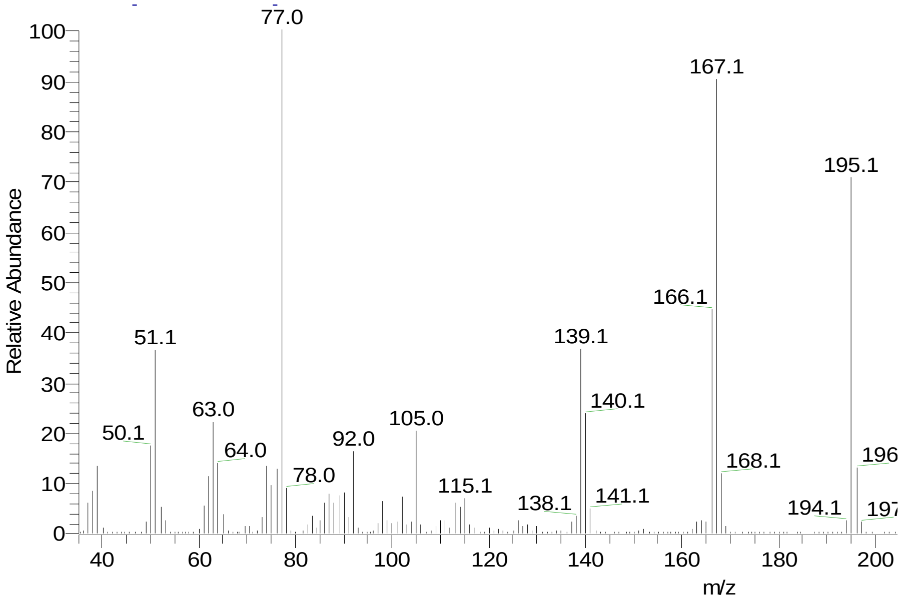


Fig.2. Mass-spectrum of 3-phenilantranil

Synthesis of acrydone. 0.157 g of 2-azidobenzophenone was boiled in 10 ml of undecane (b.p. 198 ^{o}C) for 10 h. This time is sufficient to decompose the azide completely. The solvent color changes from light-yellowish into brown-red. After cooling the dark-brown precipitate was formed. The raw material was recrystalized from boiled undecane. The absorption maxima in IR (Fig. 3) and UV spectrum (Fig. 4) are in closed resemblance with the known from literature (SDBS [3] and NIST [4] databases).

Photolysis of 2-azidobenzophenone solution. Photolysis of 2-azidobenzophenone dissolved in acetonitrile was performed in 1 cm quartz quevette. The low pressure Hg-lamp (Buf-15) was used to irradiate the relevant solutions. The concentrations were 5×10^{-4} and 5×10^{-5} M.

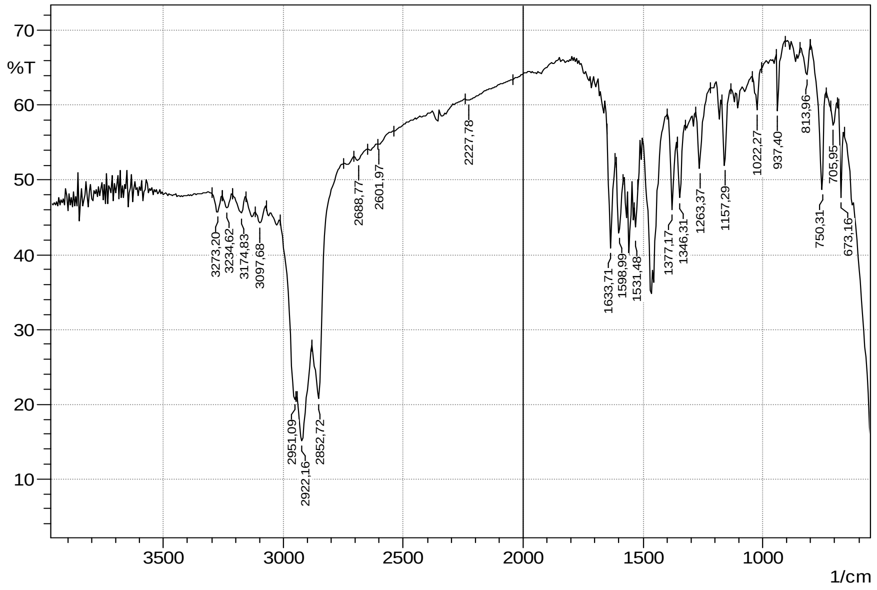


Fig.3 IR spectra of 9(10H)-acridone in nuiol

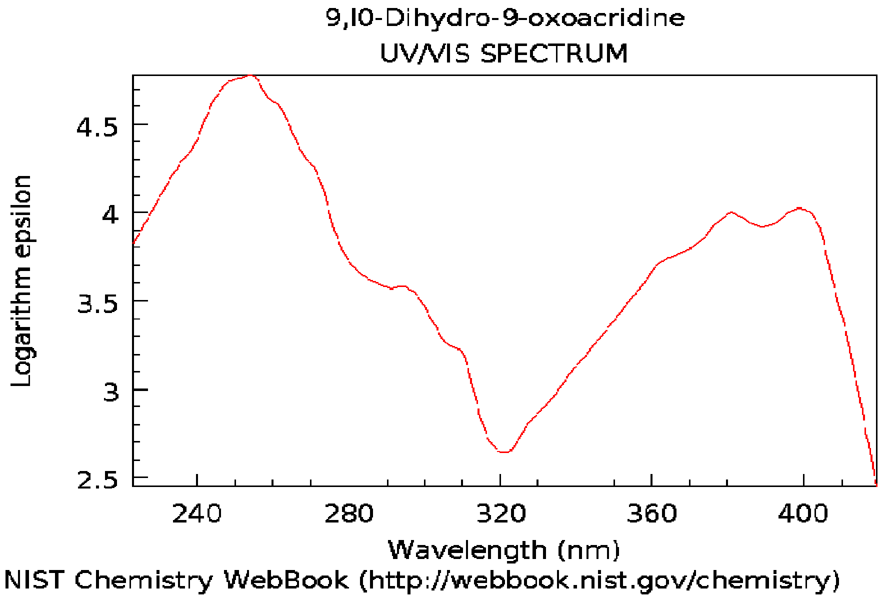


Fig. 4 UV-Vis Absorption Spectra of 9(10H)-acridone in ethanol

Measurement of UV/Vis spectra. The UV/Vis spectra of the dissolved 2-azidobenzophenone and its photolysis products were measured with Analitik Jena SPECORD-40 in 200-700 nm region.

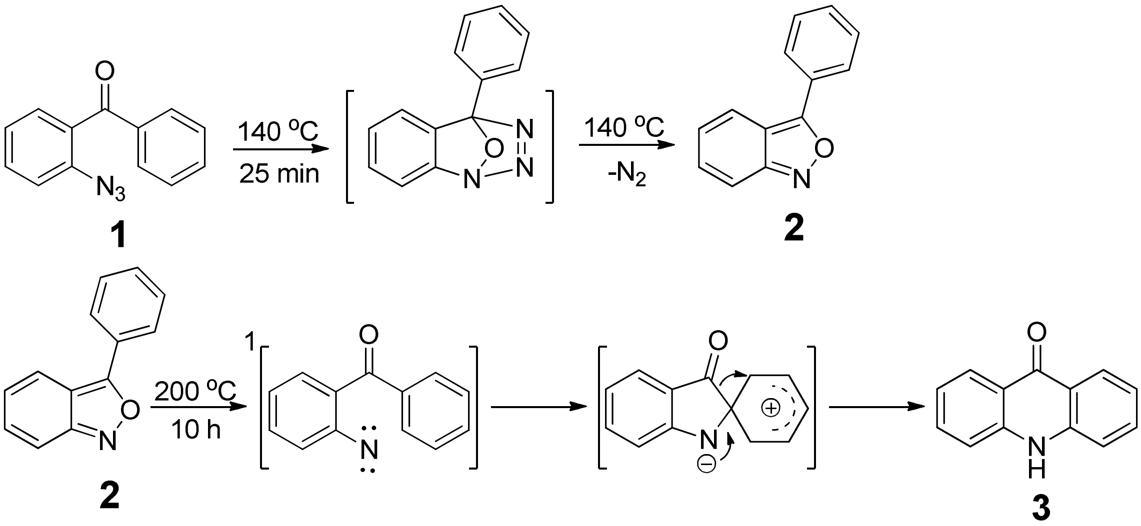
Measurement of IR spectra. IR spectra of the 2-azidobenzophenone and its photolysis products in protic and aprotic solvents were measured with IR-Furrie spectrophotometer Shimadzu IRPrestige-21 in KBr cavities in 4000-400 cm^{-1} range.

Chromatographic separation of the reaction products. In order to indentified the 2-azidobenzophenone products we used high efficiency liquid chromatographer Shimadzu LC-20 equipped with C-18 colomn. We used gradient eluting with ethanol:0.01% phosphonic acid with linear declining from 65.5% dowm to 0% in 20 min and in 25 min in pure ethanol.

Discussion

Thermolysis of 2-substituted phenylazides containing multiple bond in α and β positions relative to azide group gives rise to formation of the intramolecular cyclization products with quantitative yields. High yields of heterocycles is due to intramolecular 1,3-dipolar cycloaddition when cyclization and nitrogen loss take place simulteniously.

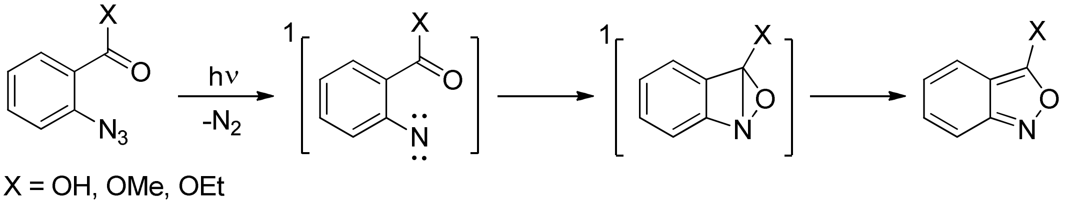
The main 2-azidobenzophenone (1) thermolysis products are 3-phenylanthranyl (2) and thermally stable 9(10H)-acrydone (3). Formation of 3 takes place in more strict conditions (under prolonged warming) (Scheme 1).



Scheme 1. Thermolysis of 2-azidobenzophenone

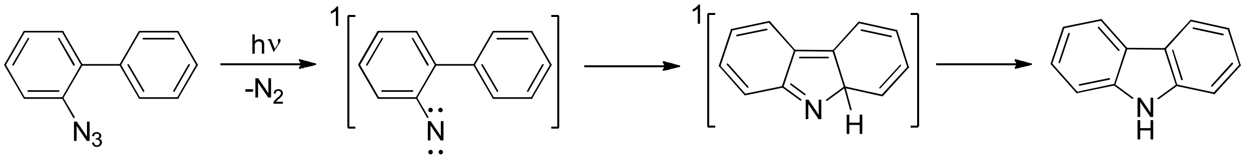
Photochemical decomposition of arylazides takes another reaction path. After UV irradiation the azide transfers into excited state and then decompose to form singlet nitrene and molecular nitrogen.

Taking into account literature data and using analogy with 2-azidobenzoic acid and its esters we proposed that nitrene formed under UV irradiation of 1 was able to insert into multiple bond of carbonyl group giving **2** (scheme 2).



Scheme 2. Photolysis of 2-azidobenzoic acid and its esters

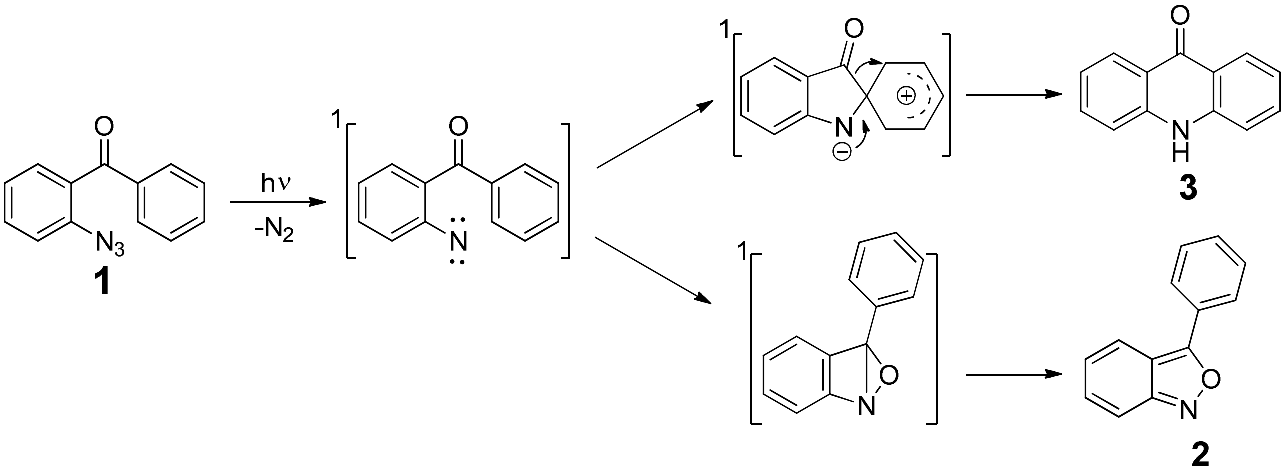
On the other hand the photochemical formation of **3** is possible in analogy with photochemical cyclization of 2-azidobiphenyl to turn into carbazole that has place with yield close to quantitative one (scheme 3).



Scheme 3. Photochemical formation of acrydone

So, we can concluded that in the course of the photolysis of 1 there is a possibility to form 3 after insertion of nitrene into C=C bond of benzene ring with simultaneous rearrangement.

So, the possible scheme of photolysis of 1 can be presented as (scheme 4):

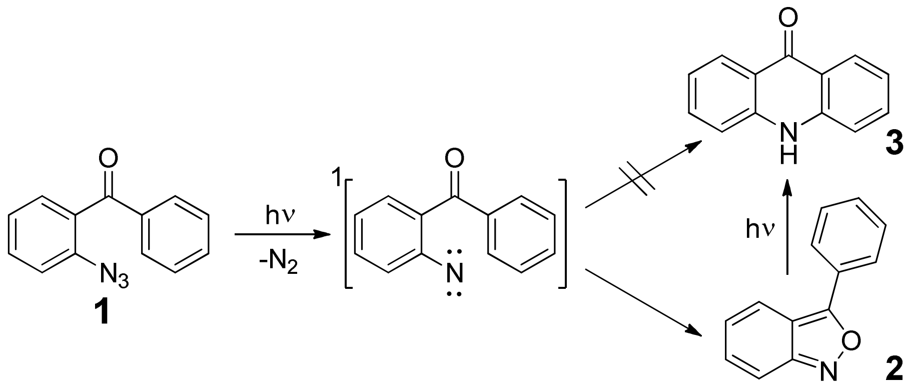


Scheme 4. Proposed scheme of the 2-azidobenzophenone photolysis

Counter synthesis of the possible photolysis products and their identification by UV/Vis spectra measuring gave us a possibility to determine characteristic bands of absorption. In the case of 2 this band is long wavelength maximum (350 nm), and for **3** the band corresponds to absorption with maxima more than 400 nm.

Separation of the photolysis products was performed by means of liquid chromatograph with diode matrix detector. They were identified by coincidence of their electronic spectra and due to retention times of the proposed reaction products in the case of **2** and **3** (scheme 5). Besides, there also were measured UV-VIS spectra of the irradiated solutions of the azides.

In the case of **1**, and of the related ketones there high quantum yield of the intersystem crossing, that means that the singlet nitrenes obtained in the course of the azide photolysis with large probability of intersystem transfer into the triplet state. The triplet state of nitrene is greatly different from the singlet state so that their cyclization is possible only as the two-step reaction. At first there has place the triplet biradical intermediate formation; at second there proceeds addition after intersystem crossing in the products.

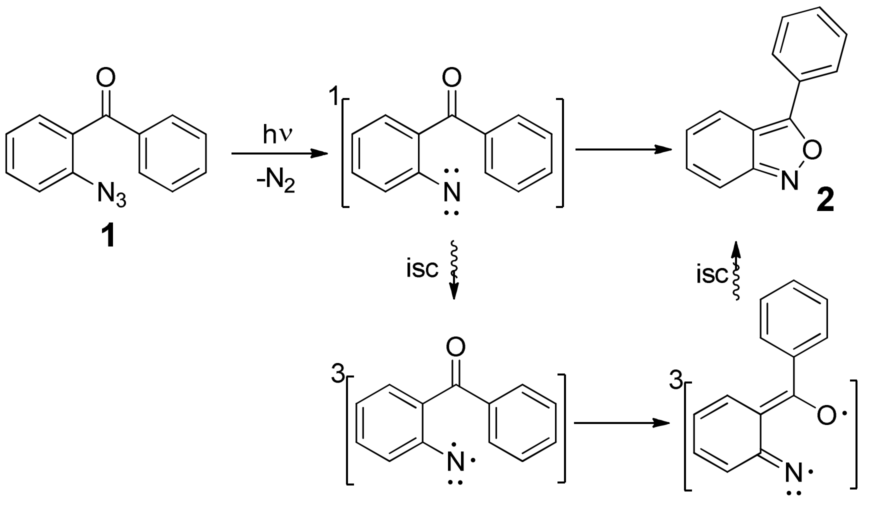


Scheme 5. The 2-azidobenzophenone photolysis

However, analysis of the UV-VIS spectra of the photolysis products for **1** gives us a possibility to conclude that at small irradiation times of the azide solution in acetonitrile (5×10^{-5} M) there was observed an increase of absorption of 2 with isobestic point preservation that evidence that there has place formation of 2 with yields close to quantitative ones. Prolonged irradiation disturbs the isobestic point preserving, however the increase of absorbance in the region of absorbance of 3 was not observed.

Photolysis of 2 in the experimental conditions used does not form 3.

High yields of 2 from the photolysis (Scheme 6) and the high quantum yield of intersystem crossing of nitrenes forced us to propose the triplet path of their cyclization. It is possible that the triplet nitrene formed isomerizes into the *ortho*-quinone type biradical product with possible electron density localization on the oxygen atom of carbonyl group and the nitreneous nitrogen atom. Due to electron density redistribution this particle is more stable than the triplet nitrene and being not reactive forms 2 after the second change of the spin state.



Scheme 6. The 2-azidobenzophenone photolysis

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