

Photolysis of 2-azidobenzoic acid in aprotic solvents in the presence of water

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Abstract

The photochemically generated singlet nitrene insertion into a double bond of an *ortho*-substituent and C=C bond at a benzene ring was investigated. The insertion into the double bond has to give a condensed heterocycle, but the insertion into a benzoic cycle produces an enlarged cycle up to unstable 1,2-didehydroazepin (DDHA). An addition of a nucleophilic agent required to form stable 3H-azepin, and upon an equilibrium "singlet nitrene - DDHA" establishment it is shifted to the DDHA formation. It results in decreasing of the condensed heterocycle compound yield and increase of the 3H-azepin yield.

To test this assumption we have investigated an addition of water molecules to the reaction system effect upon yields of 3H-azepin-2-one-3-carboxylic acid and of 2,1-benzisoxazol-3(1H)-one in the course of the 2-azidobenzoic acid decomposition in aprotic solvents. It was stated that an increase of water amount in the reaction system will produce simultaneous increase both of the heterocycle compound and 3H-azepin.

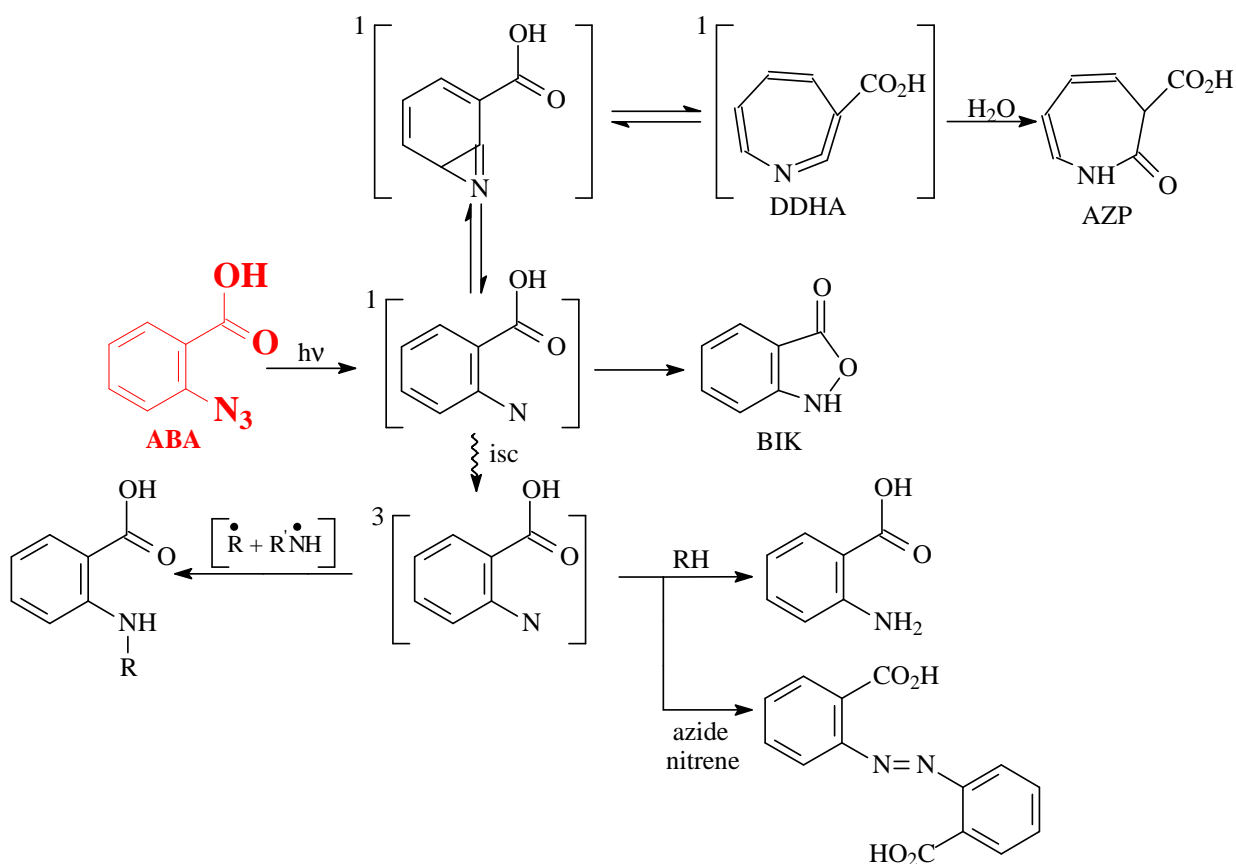
We have proposed that in the absence or small amount of nucleophilic additives 2,1-benzisoxazol-3(1H)-one can react with DDHA to form a complicated mixture of photolysis products, and thus to decrease of the heterocycle compound yields.

Keywords: 2-azidobenzoic acid, 3H-azepin-2-one-3-carboxylic acid, 2,1-benzisoxazol-3(1H)-one, 1,2-didehydroazepin, photochemistry of aromatic azide, photolysis, nitrenes.

Introduction

The great majority of photochemical reactions proceeds with formation of radicals and other short-lived intermediates. Their high reactivities and sets of consecutive rearrangements make the mechanisms involved to be very complicated and produce many different reaction products with small outputs. However, sometimes the special structure of a reagent gives rise to only some from possible reaction paths. The studies of the reaction environment and reaction parameters influence upon the product outputs give a deeper understanding of the reaction mechanisms and intermediates involved.

It is known that aromatic azides dissociate to form singlet nitrenes. Aryl azides with unsaturated chains in the ortho-site cyclize to form condensed N-containing heterocycles [1,2]. In the other case, singlet nitrenes isomerizes and turn into more stable and less reactive state.



Scheme 1. The photolysis of 2-azidobenzoic acid.

The following reaction could be identified as to be such reaction type: insertion into benzene ring with the ring enlargement to form unstable 1,2-didehydroazepines (DDHA) [3], the said reaction is being characteristic only for aromatic nitrenes. The next possibility is to interconvert into the triplet state. The reactivity of the intermediates decrease gives rise to increase of possibility or bimolecular reactions.

Studies of influence of concentration of nucleophilic agent in a solution upon condensed heterocycle yield and upon yield of DDHA isolated as substituted 3H-azepin being a product of interaction with nucleophiles give us an opportunity to reveal an possibility of the tautomeric equilibrium between singlet nitrene and DDHA. So as in the case of the singlet nitrene existence in the two tautomeric forms and under nucleophilic concentration increase should shift the equilibrium to the DDHA formation site and produce an increase of the substituted 3H-azepin yield with simultaneous decrease of the condensed heterocycle yield. When the tautomeric equilibrium is absent then the condensed heterocycle yield should not change as the nucleophil

concentration in a solution changes.

To check such proposal we studied an influence of water addition upon the 3H-azepin-2-one-3-carbonic acid and of 2,1-benzisoxazol-3(1H)-one yields in the case of the 2-azidobenzoic acid photolysis in aprotic solvents.

Experimental Procedure

Solvent preparation. The solvent were purified by standard procedures. The trace amounts of water were removed by drying with activated molecular sieves (4 Å). Ethanol was absolutized by storing above anhydrous CuSO_4 .

Synthesis of 2-azidobenzoic acid (2-azidobenzoic acid). 2-azidobenzoic acid was synthesized by diazotizing of hydrochlorous solution of 2-aminobenzoic acid at 0-5 °C with NaNO_2 . Sodium azide was added into the diazonium salt solution and continuously warmed up to room temperature. Warming destabilized the diazonium salt and produced substitution of it by azido group. The azide synthesized were isolated as crystalline white precipitate. It was filtered out, washed by cold water and dried in darkness at room temperature. The raw azide was recrystallized from heptane – benzene mixture.[4] M.p. = 144 °C. IR (nujol mull, cm^{-1}): 2131.34, 2110.12, 2081.19 ($\nu_{\text{as}} \text{N}_3$); 1691.57 ($\nu \text{C=O}$); 1267.23 ($\nu_{\text{s}} \text{N}_3$). UV-Vis in acetonitril ($\lambda_{\text{nm}} / \lg(\epsilon), \text{M}^{-1} \times \text{cm}^{-1}$): 221/4.29, 255/3.99, 296/3.43.

The ABA solution photolysis. The 2-azidobenzoic acid solution photolysis in protic and aprotic solvents was conducted in quartz cavities having 1 cm optical path. The solutions were illuminated by the UV low pressure Hg-lamp BUF-15 (more than 80% of its u.v. light has wave length of 253.7 nm). Concentration of azide in the solution was 6×10^{-3} M.

Measurement of IR spectra. IR spectra of the 2-azidobenzoic acid solutions and the products of its photolysis in protic and aprotic solvents were measured by means of IR-Furie spectrophotometer Shimadzu IRPrestige-21 in the KBr cavities at 4000-400 cm^{-1} .

Measurement of electronic spectra of absorbance. Spectra of solutions of 2-azidobenzoic acid and its photolysis products registered on the device Analitik Jena SPECORD-40 in the wavelength range of 210-700 nm.

Measurement of NMR spectra. To obtain NMR spectra 20 mg of isolated 3H-azepin-2-one-3-carbonic acid was desolved in 7 ml of 3H-azepin-2-one-3-carbonic acid DMSO-d_6 . The spectra were measured by Varian 400 MR NMR-spectrometer and analyzed by means of MestReNova 7 program.

Chromatographic separation of the reaction products. To identify the reaction products of the ABA photolysis we used high effective liquid chromatographer Shimadzu LC-20, equipped with C-18 column and gradient washing with mixture of ethanol: 0.01 % of

phosphonic acid with linear decreasing from 65.5% up to 0% in 20 min and after that we used washing in ethanol in 25 min.

Synthesis of 3H-azepin-2-one-3-carbonic acid. 350 mg of 2-azidobenzoic acid was dissolved in 12 ml of acetonitril with 30 ml of water added. The solution was irradiated 24 h with stirring. The solvent was removed from the reaction mixture in vacuo. 3H-azepin-2-one-3-carbonic acid was isolated by means of preparative column chromatography using silicagel and acetone-ethanol mixture (1:1) as an eluent.

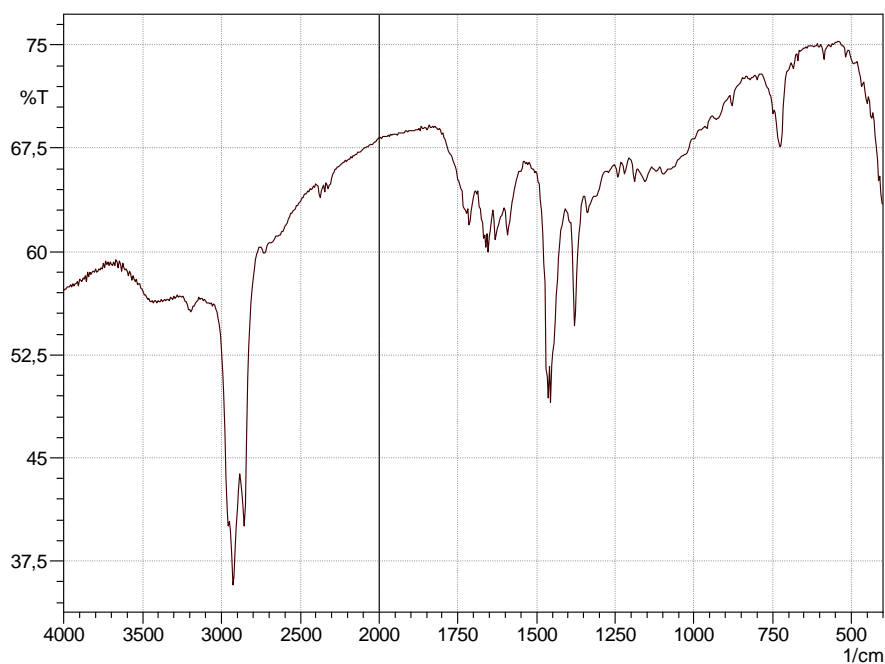


Figure. 1. IR spectra of 3H-azepin-2-on-3-carboxylic acid in nujol

Characteristic frequencies in IR spectrum in the nujol mull (Fig. 1) and spectrum ^1H NMR (Fig. 2) deuterated DMSO coincided with the published data [5].

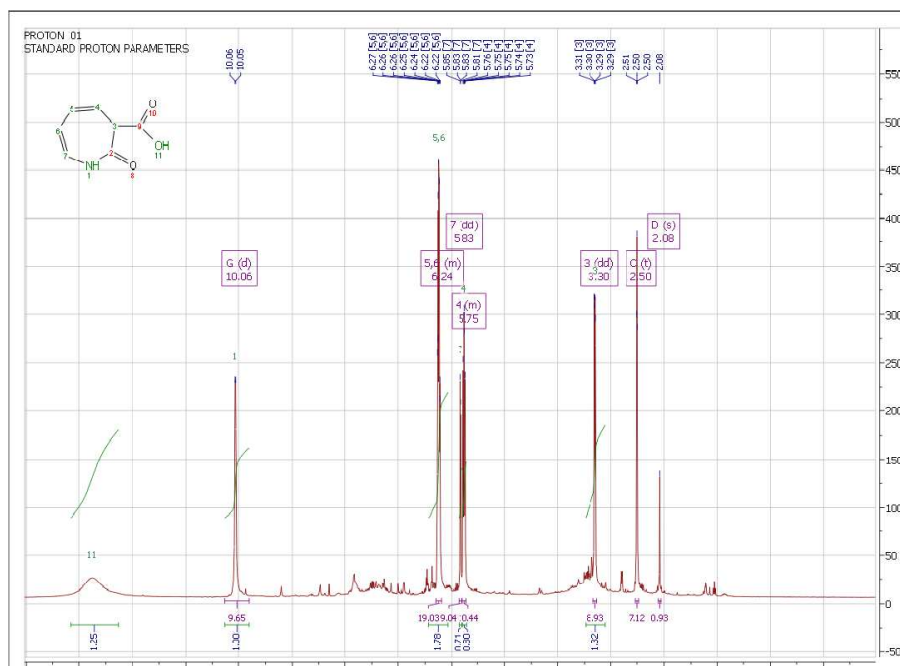


Figure. 2. ^1H NMR spectrum of 3H-azepin-2-on-3- carboxylic acid

Results and their discussion

High effective liquid chromatography was used to study influence of water and ethanol added into acetonitrile, dioxane, and tetrahydrofuran upon yields of 2,1-benzisoxazol-3(1H)-one and 3H-azepin-2-on-3- carboxylic acid from the 2-azidobenzoic acid photolysis. Quantitative determination of the yields was produced with chromatography.

The basic emission line of the u.v. light source used in our studies coincides with the absorption maximum of 2-azidobenzoic acid and simultaneously with the absorption minimum of 2,1-benzisoxazol-3(1H)-one (Fig. 3).

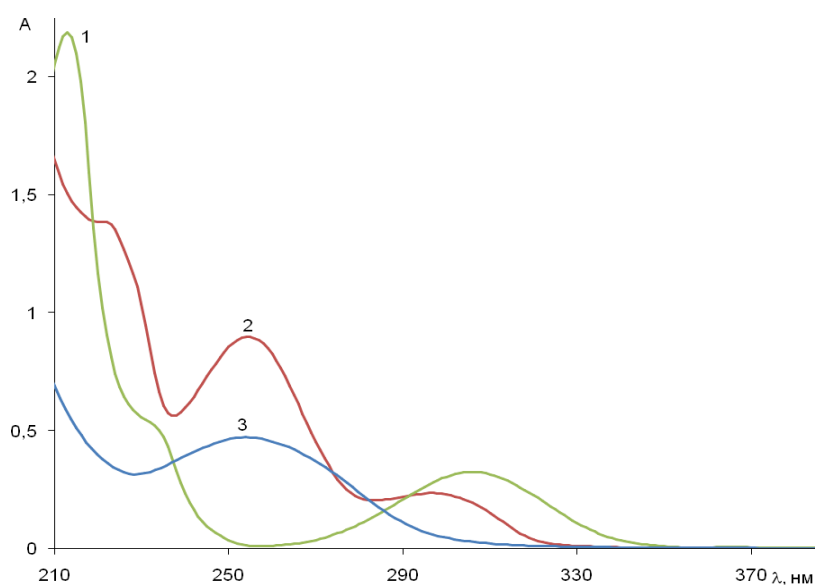


Figure. 3. UV-Vis Absorption Spectra of 2,1-benzisoxazol-3(1H)-one (1) and 2-azidobenzoic acid (2) 3H-azepin-2-one-3-caboxilyc acid in acetonitril.

Our choice of the lamp gave us an opportunity to exclude the secondary photolysis of 2,1-benzisoxazol-3(1H)-one in the course of the arylazide decomposition. Light sensitivity of 2,1-benzisoxazol-3(1H)-one was not studied in our work, but taking it as being analogical to the 3-methyl-2,1-benzisoxazole photolysis [6], its decomposition in the presence of water should give 3H-azepin-2-one-3-carboxylic acid. The azepin formed was stable under u.v. irradiation of the intensity used.

Based on the hypothesis, we must conclude that the yield of 2,1-benzisoxazole-3 (1H)-one solution with the concentration of water will not be changed or reduced. However the increase of water content in the solution gave rise to simultaneous increase of both 2,1-benzisoxazol and 3H-azepin-2-on-3- carboxylic acid (Fig.4,5)

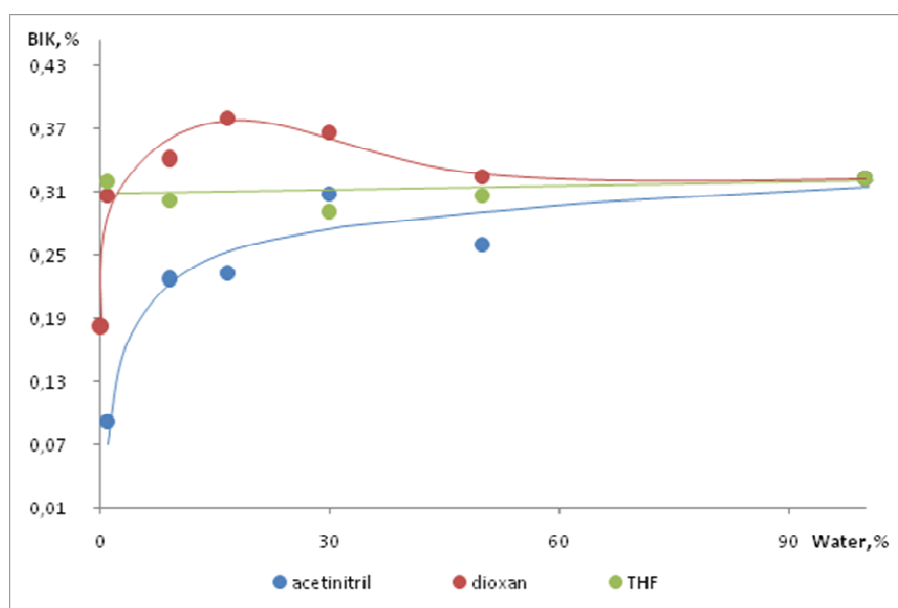


Figure. 4. Effect of water on the yields 2,1- benzisoxazol-3(1H)-one (BIK)

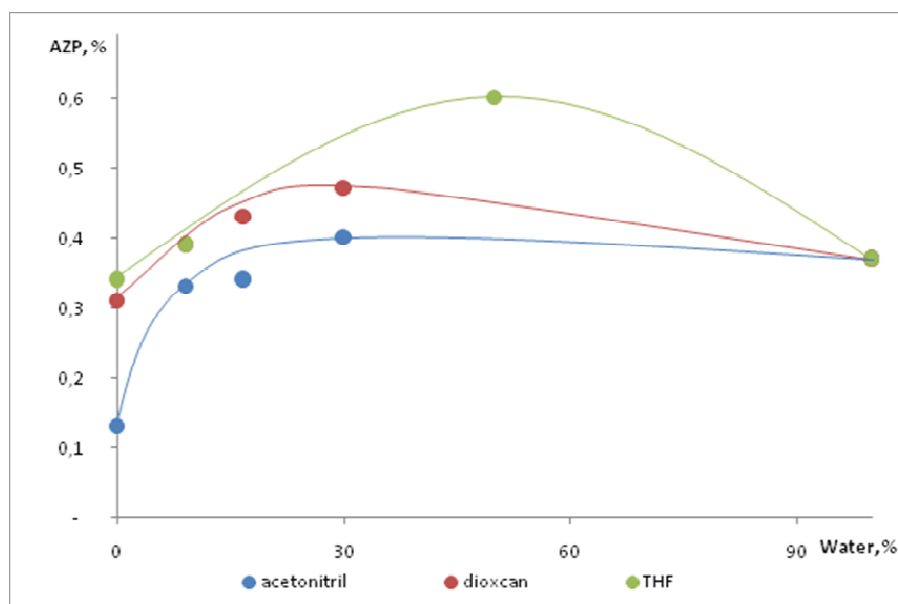


Figure. 5. Effect of water on the yields 3H-azepin-2-on-3-carboxylic acid (AZP)

We have proposed that symbate increase of the products yields is connected with nucleophilic nature of 2,1-benzisoxazol-3(1H)-one. In that cas there has place a competition of interaction of 1,2-dehydroazepin with water and other nucleophilic agents that are formed in the course of reaction with 2,1-benzisoxazol-3(1H)-one. In the absence of any nucleophil 1,2-dehydroazepin interacts with N-H group of 2,1-benzisoxazol-3(1H)-one that decrease its yields. If there are nucleophils in the solvent 1,2-dehydroazepin interacts both with them and with 2,1-benzisoxazol-3(1H)-one. In the case there has place formation of 2-substituted 3H-azepins and simulteneos increase of 2,1-benzisoxazol-3(1H)-one, so as it is not consumed in the secondary reaction, and under greater nucleophil concentration the consumption of 2,1-benzisoxazol-3(1H)-one in the reaction is not essential.

If we use solvents containing water and ethanol there can be observed a competition of interaction of 1,2-dehydroazepin with water and ethanol that produces linear increase the yield of 3H-azepin-2-on-3-carboxylic acid with increase of water content in the solution (Fig. 6). Yield of 2,1-benzisoxazol-3(1H)-one does not change in the case.

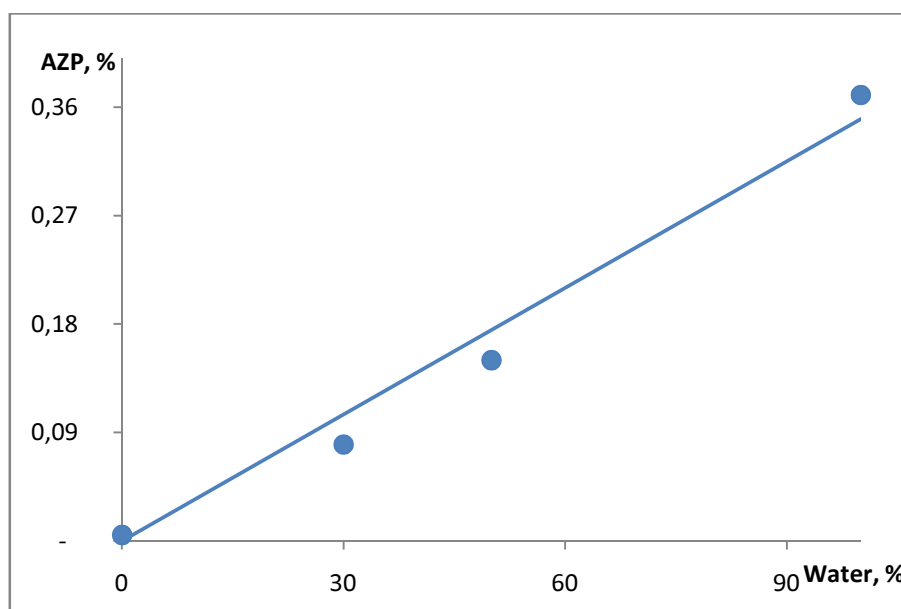


Figure. 6. Effect of water on the yields 3H-azepin-2-on-3-carboxylic acid (AZP) in ethanol

The most interesting data were obtained in the study of the azide photolysis in dioxane and tetrahydrofuran. We have observed maximum of the yield in comparison with acetonitrile. In the mixture with water they are greater than in pure water. It may be connected with coordination of solvent molecules to the singlet nitrene or to 1,2-dehydroazepin. The formation of electron density redistributes intermediates. As a result their reactivity decreases and lifetime increases. The latter gives rise to an increase of bimolecular reaction contribution to the reaction.

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