Vol. 91, No. 1, 1979 BIOCHEMICAL AND BIOPHYSICAL RESEARCH COMMUNICATIONS
November 14, 1979 Pages 375-382

THE FURTHER INVESTIGATION OF PHYSICAL AND PHOTOCHEMICAL PROPERTIES OF QUASIMETACYCLOPHANE DERIVED FROM THYMINE

Henryk Koroniak, Bohdan Skalski
and Krzysztof Golankiewicz

Institute of Chemistry, Adam Mickiewicz University
60-780 Poznań, Poland

Received September 6, 1979

Summary
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The thymine derived quasimetacyclophane exists in two conformers a and b. The absorption spectra of a and b were evaluated and the conformational equilibrium in different solvents /H_2O : EtOH/ were examined. The rate constant k_{-1} for reaction b ⟶ a was established as well as E_a.

Introduction

In the recent paper [1] we have described the synthesis and preliminary physical properties of quasimetacyclophanes derived from 5-alkyl-uracils. The model compounds for dinucleotides in which phosphoribose bridge is substituted by a polymethylene chain were succesfully introduced by N.J. Leonard [2-6] for the investigation of base-base interactions, photodimerization and controlling of the inter-ring interactions. In the current paper we present the photochemical and physical studies of quasimetacyclophane derived from thymine.
It was found that this compound exists in two isomers a and b /Scheme 1/.

Photochemical properties of thymine derived quasimetacyclophane

Thymine derived quasimetacyclophane undergoes very easily photodimerization yielding only one photoproduct-

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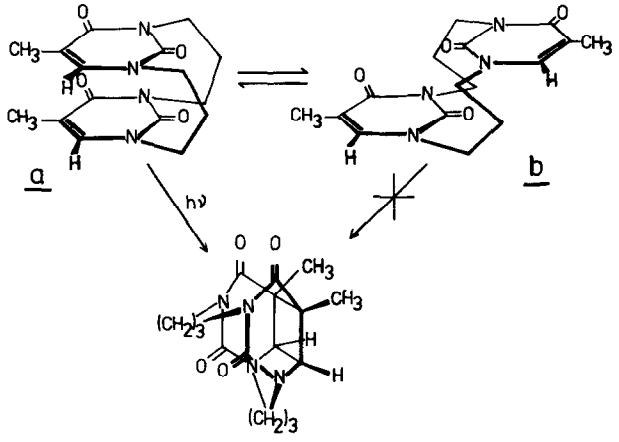

SCHEME 1

-cyclobutane type photodimer[1] . The reaction can be carried out using for irradiation both long / $\lambda > 290$ nm/ and short / $\lambda = 254$ nm/ wavelength light, what was reported previously[1] .

The NMR spectra of this compound suggested that the compound exist in two conformational forms a and b. The two dimensional TLC showed that after separation of conformers a and b in one direction, then irradiated with UV light and separation in second direction only conformer a showed to be able to produce photodimer, and b remained inactive. These results led us to the conclusion that only a can undergo photodimerization.

Structures of a and b are based on the inspection of Dreiding models. The distance between planes of pyrimidine moieties in conformer a is about 2-4 Å what is similar to nucleic acids. It was proved in several papers that the main role in photodimerization plays reciprocal orientation of two C/5/=C/6/ double bonds of pyrimidine rings. In conformer a this requirement is fullfiled and this is the reason that even light $\lambda = 254$ nm could produce the photodimer /i.e. the transition state is stable enough to react yields photodimer/.

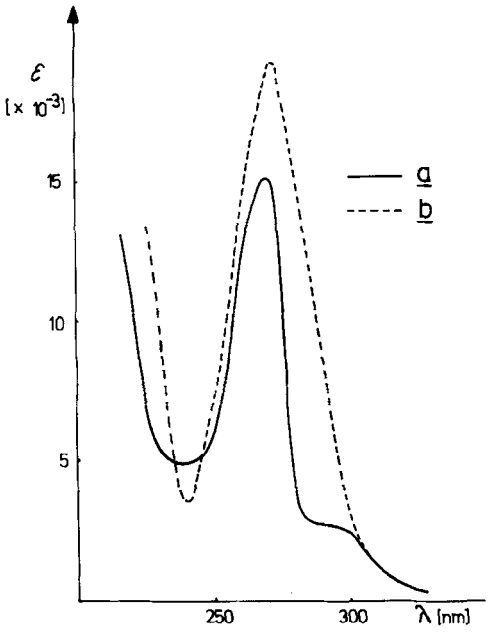

Fig. 1. The absorption spectra of a and b conformers.

Conformational equilibrium a ⇌ b

We have not been able to isolate the pure conformers a and b preparatively. In our work we have calculated the quantitative absorption spectra of a and b /Fig. 1/. This was based on the assumption that the conformer b should have the absorption spectrum very similar to spectrum of 1-n-propyl-thymine /multiplied 2x/ /see Experimental/.

These spectra need some comments. The spectrum of isomer b corresponds with the spectrum of 1-n-propyl-thymine x 2 /to the calculation only λ = 272 nm and ε = 9110 were used-not the full spectrum/. The spectrum of a is quite different and shows the additional band of absorption at about λ = 295 nm. The shape of spectrum suggests the exciton structure caused by strong interactions between two electron systems in pyrimidine fragments [7]. The hypochromism calculated on the basis of these data gives that %H

Table 1. Percentage of conformers a and b in water:ethanol solutions /at 20°C/.

Solvent	% a	% b	$K = \frac{[b]}{[a]}$ /x 10^2/
H_2O	95,4	4,6	4,82
25% EtOH	91,4	8,6	9,41
50% EtOH	88,0	12,0	13,64
75% EtOH	85,4	14,6	17,10
100% EtOH	81,3	18,7	23,04

for a is very high %H=28% /in comparison for 1,1'-trimethylene-bis-thymine, %H=10,5/ whereas for b %H=0.

The additional evidence of the very strong interaction between two pyrimidine bases in thymine derived quasimetacyclophane can be taken from the measurements of quantum yield of photodimerization. The measured value of φ_{dim} = = 0,18 ± 0,05 for conformer a at λ = 313 nm. This value is an order higher than in the case of 1,1'-trimethylene-bis-thymine /where φ_{dim} = 0,04 at $\lambda > 290$ nm/.

The conformational equilibrium depends strongly on the solvents. In water ratio of conformers a : b is about 20,7 whereas in 96% ethanol only 4,3 /Table 1/.

The solutions of thymine derived quasimetacyclophane in solvents with various amount of ethanol in water were irradiated to the equilibrium state[+/]. The ratios of opti-

[+/] This is a state when during further irradiation /at room temperature was not observed decrease in optical density at λ_{max} at reasonable time/none detectable changes during 30 minutes of irradiation at $\lambda > 290$ nm/. This can not be taken as the photostationary

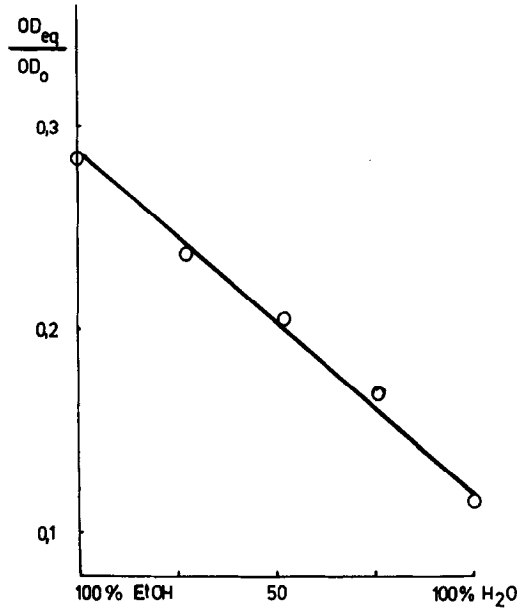

Fig. 2. Ratios of optical density at equilibrium state to optical density before irradiation /λ_{max} = = 272 nm/ as a function of composition of solvent.

cal density at λ = 272 nm at equilibrium state to optical density before irradiation as a function of composition of solvent are shown in Fig. 2.

From these results it is easy to conclude that in more polar solvents /H_2O/ exist mostly conformer a whereas amount of b increase in less polar solution /such as EtOH/. The inspection of Dreiding models led us to the suggestion that the water can stabilize the structure of conformer a. The structure of possible hydrate is shown in Fig. 3. /This structure was chosen as the example because molecules of water fit very well to the structure of a conformer/. On the basis of absorption spectra of a and b and photodimer we performed the kinetic investigation to evaluate the rate constant of reaction b → a.

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state because of conformational changes what makes possible further reaction according to Scheme 1.

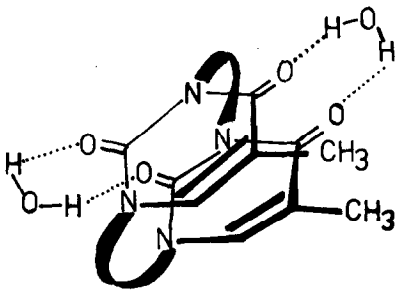

Fig. 3. Structure of hydrate of thymine derived quasimetacyclophane /proposed/.

The reaction could be described as follows:

$$\underline{a} \underset{k_{-1}}{\overset{k_1}{\rightleftharpoons}} \underline{b} \qquad K = \frac{k_1}{k_{-1}} = \frac{[\underline{b}]}{[\underline{a}]}$$

The values of K are collected in Table 1 for different solutions of thymine derived quasimetacyclophane. According to Scheme 1 it is possible to remove the a conformer from solution by irradiation process. After this the equilibrium state can be monitored by UV spectroscopy and changes of spectra can be registered as a function of time. These changes are caused by reaction $\underline{b} \longrightarrow \underline{a}$.
On the basis of these data we evaluated the rate constant k_{-1} /Table 2/. From the temperature dependence of rate

Table 2. Rate constant k_{-1} /in 50% H_2O : 50% EtOH v : v/ for reaction $\underline{b} \longrightarrow \underline{a}$.

Temperature [°C]	k_{-1} x 10^3
40	1,23
45	2,13
50	3,24
55	5,42
60	9,13
65	13,30

constant the E_a and A are calculated: E_a = 12,7 kcal and $A = 1,6 \times 10^6$.

Experimental

All UV quantitative measurements were performed on Cary 118 spectrophotometer at least three times and the average values are reported. As the solvents double distilled, deionized water and pure for spectroscopy ethanol were used. In irradiation in photochemical experiments the following lamps were used:

1. TQ 150 Original Hanau lamp with cylindrical Pyrex filter as a source of a light $\lambda > 290$ nm
2. TNN 15 Original Hanau lamp as a source of light λ = = 254 nm.

The irradiation for determination the equilibrium state were carried out in cylindrical Pyrex reactor and for kinetic studies and quantum yield measurements in quarz kuvette.

For determination of quantitative absorption spectra of conformers a and b the solution of thymine derived quasi-metacyclophane /in 50 H_2O : 50 EtOH = v : v/ was irradiated to equilibrium state at 20°C according to equation /Scheme 1/.

$$a + b \longrightarrow \text{photodimer} + b$$

We assumed that the conformer b should have absorption spectrum very similar to 1-n-propyl-thymine /multiplied 2x/ because its structure shows that it consist of two isolated, almost independent electron systems.

Thus we assumed for b: λ_{max} = 272 nm and ε_{max} = 19.220 /for 1-n-propyl thymine ε_{max} = 9610/.

On the basis that also the spectrum of photodimer is known [1] it alloved us to calculate the absorption spectrum of b. From spectrum of irradiated mixture a + b, the spectrum of a was calculated.

The hypochromism %H was calculated an the basis of absorption spectra a and b according to rules described previously [2] . The quantum yield of photodimerization of a was determined at λ = 313 nm /irradiation was carried out using the interference filters/ using uranyl actinometer.

For studying the reaction b⟶ a the irradiated solutions at equilibrium state /contained only photodimer and b/ were placed in thermostated holder in Cary 118 spectrophotometer and the changes of absorption spectra were registered during the time. For the determination of k_{-1} the concentrations of a and b were calculated on the basis of optical density OD at λ = 290 nm /the photodimer have in this region only end of absorption and do not disturb in this measurements/.

The temperature dependance of k_{-1} gave the values of E_a and A according to Arrhenius equation.

Acknowledgment

This work was supported by the Polish Academy of Sciences.

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