

ACID-CATALYZED PHOTOREACTION OF 6-CHLORO-1,3-DIMETHYLURACIL TO *p*- AND *m*-XYLENE: FORMATION OF NOVEL PHOTOCYCLOADDUCTS, 6-METHYLENE-9,11,X-TRIMETHYL-9,11-DIAZAPENTACYCLO[6.4.0.0<sup>1,3</sup>.0<sup>2,5</sup>.0<sup>4,8</sup>]DODECANE-10,12-DIONES AND 5-METHYLENE-9,11,X-TRIMETHYL-9,11-DIAZAPENTACYCLO[6.4.0.0<sup>1,3</sup>.0<sup>2,6</sup>.0<sup>4,8</sup>]DODECANE-10,12-DIONES<sup>1</sup>

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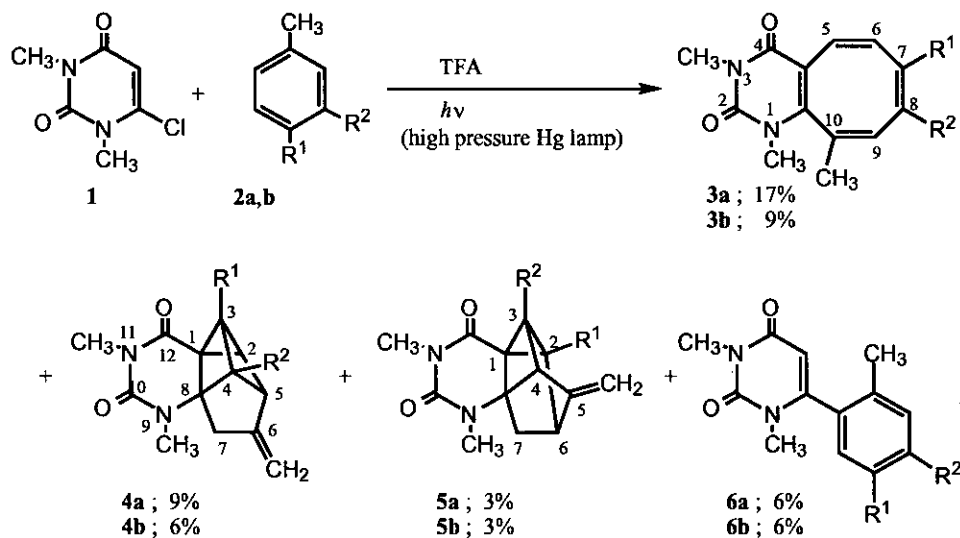
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**Abstract**-----Uv irradiation of 6-chloro-1,3-dimethyluracil in *p*- and *m*-xylenes in the presence of trifluoroacetic acid gave novel photocycloadducts, 6-methylene-9,11,x-trimethyl-9,11-diazapentacyclo[6.4.0.0<sup>1,3</sup>.0<sup>2,5</sup>.0<sup>4,8</sup>]dodecane-10,12-diones and 5-methylene-9,11,x-trimethyl-9,11-diazapentacyclo[6.4.0.0<sup>1,3</sup>.0<sup>2,6</sup>.0<sup>4,8</sup>]dodecane-10,12-diones, together with tetramethylcyclooctapyrimidine-2,4-diones as the sole regioisomer. The modes of the cycloaddition were discussed.

In the course of our studies on the acid-catalyzed photoreaction of pyrimidine bases with substituted benzenes, we have reported that 1,3-dimethylcyclooctapyrimidine-2,4-diones were produced by the photolysis of 6-chloro-1,3-dimethyluracil (**1**) in benzene<sup>2</sup> and its monosubstituted derivatives<sup>3</sup> in the presence of trifluoroacetic acid (TFA), presumably *via ortho*-cycloaddition. In order to explore the general feature of this photocycloaddition reaction, we have extended our work to disubstituted benzenes. In the present paper, we describe our findings that photoreaction of **1** in *p*- and *m*-xylenes (**2a, b**) afforded cyclooctapyrimidine derivatives (**3a, b**) and two novel pentacyclic compounds consisting of 3, 4, 4, and 5-membered rings (**4a, b**) and 3, 4, 5, and 5-membered rings (**5a, b**) probably *via* multi-photon reactions. On the basis of the substitution sites of the methyl groups, compounds **3(a,b)** and **4(a,b)** are presumed to be derived *via ortho*-addition, while the compounds **5(a,b)** may be the products through *meta*-addition.

Uv irradiation of **1** in *p*-xylene (**2a**) in the presence of trifluoroacetic acid (TFA) was shown to give numerous products by hplc. Chromatography of the reaction mixture afforded three types of cycloadducts as the single regioisomers; *i. e.*, 1,3,7,10-tetramethylcyclooctapyrimidine-2,4-dione (**3a**) and two novel

pentacyclic compounds, 6-methylene-3,9,11-trimethyl-9,11-diazapentacyclo[6.4.0.0<sup>1,3</sup>.0<sup>2,5</sup>.0<sup>4,8</sup>]dodecane-10,12-dione (**4a**) and 5-methylene-2,9,11-trimethyl-9,11-diazapentacyclo[6.4.0.0<sup>1,3</sup>.0<sup>2,6</sup>.0<sup>4,8</sup>]dodecane-10,12-dione (**5a**), together with 6-substituted products, 1,3-dimethyl-6-(*p*-xylyl)uracil (**6a**) and 1,3-dimethyl-6-(*p*-methylbenzyl)uracil (**7**). Similarly the photoreaction with *m*-xylene (**2b**) afforded 1,3,8,10-tetramethylcyclooctapyrimidine-2,4-dione (**3b**) and two pentacyclic compounds, 6-methylene-4,9,11-trimethyl-9,11-diazapentacyclo[6.4.0.0<sup>1,3</sup>.0<sup>2,5</sup>.0<sup>4,8</sup>]dodecane-10,12-dione (**4b**) and 5-methylene-3,9,11-trimethyl-9,11-diazapentacyclo[6.4.0.0<sup>1,3</sup>.0<sup>2,6</sup>.0<sup>4,8</sup>]dodecane-10,12-dione (**5b**).



**a**; R<sup>1</sup> = CH<sub>3</sub>, R<sup>2</sup> = H; **b**; R<sup>1</sup> = H, R<sup>2</sup> = CH<sub>3</sub>. Yields are given based on **1** consumed.

Scheme 1

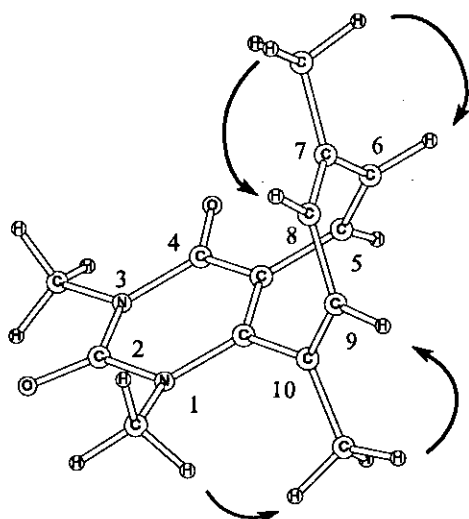


Figure 1. NOE correlation for **3a**: The optimized structure was obtained by the PM3 method.

The structural assignment of 1,3,7,10-tetramethylcyclooctapyrimidine-2,4-dione (**3a**), colorless crystals, was made essentially on the basis of ms and <sup>1</sup>H-nmr spectrum. The ms of **3a** showed the molecular ion peak (M<sup>+</sup>) at *m/z* 244 (100%). The <sup>1</sup>H-nmr spectrum exhibited four signals at δ 1.70, 1.93, 3.22, and 3.27 ppm due to the N- and C-methyl groups and peaks ascribable to four vinyl protons between δ 5.83–6.18 ppm. In a differential nuclear Overhauser effect (differential NOE) experiment on **3a**, irradiation of the N<sup>1</sup>-methyl signal at δ 3.27 caused selective enhancement of the C<sup>10</sup>-methyl signal at δ 1.93. The NOEs for N<sup>1</sup>-methyl and H-9 at δ 6.04 were observed on irradiation at C<sup>10</sup>-methyl signal. Strong NOE for H-8 at δ 5.83 and weak NOE for H-6

at  $\delta$  5.93 were observed on irradiation at C<sup>7</sup>-methyl signal (Figure 1). Similarly the structural assignment of **3b** was made on the basis of <sup>1</sup>H-nmr including NOE measurements. <sup>1</sup>H-<sup>1</sup>H Coupling constants of **3a, b** including C-methyl groups were determined by triple resonance methods. The coupling constants of vinyl protons of **3(a,b)**,  $J_{5-6}$ ,  $J_{7-8}$ ,  $J_{9-10}$  = *ca.* 11~12 Hz and  $J_{6-7}$ ,  $J_{8-9}$  = *ca.* 3~4 Hz revealed the configurations to be all *cis*<sup>4</sup> (see experimental section).

Table 1. <sup>13</sup>C-Nmr and <sup>1</sup>H-nmr data for **4a**<sup>a)</sup> and **4b**<sup>b)</sup>

| Position                         | <b>4a</b>           |                      | <b>4b</b>           |                      |
|----------------------------------|---------------------|----------------------|---------------------|----------------------|
|                                  | <sup>13</sup> C-Nmr | <sup>1</sup> H-Nmr   | <sup>13</sup> C-Nmr | <sup>1</sup> H-Nmr   |
| 1                                | 46.53               |                      | 41.89               |                      |
| 2                                | 34.61               | 2.82 (dd, 5.1, 2.6)  | 27.23               | 2.81 (dd, 3.4, 2.4)  |
| 3                                | 32.54               |                      | 38.66               | 3.38 (d, 3.4)        |
| C <sup>3</sup> -CH <sub>3</sub>  | 10.50               | 1.45 (3H, s)         |                     |                      |
| 4                                | 50.64               | 2.78 (dd, 5.1, 4.4)  | 59.05               |                      |
| C <sup>4</sup> -CH <sub>3</sub>  |                     |                      | 13.85               | 1.18 (3H, s)         |
| 5                                | 51.17               | 3.65 (dd, 4.4, 2.6)  | 58.54               | 3.28 (d, 2.4)        |
| 6                                | 147.31              |                      | 148.03              |                      |
| C <sup>6</sup> =CH <sup>a</sup>  | 106.96              | 4.73 (t, 2.5)        | 107.58              | 4.76 (t, 2.3)        |
| C <sup>6</sup> =CH <sup>b</sup>  |                     | 4.90 (t, 2.5)        |                     | 4.92 (t, 2.3)        |
| 7 (H <sup>a</sup> )              | 35.07               | 2.52 (dt, 16.9, 2.5) | 34.61               | 2.66 (dt, 17.1, 2.3) |
| 7 (H <sup>b</sup> )              |                     | 2.42 (dt, 16.9, 2.5) |                     | 2.53 (dt, 17.1, 2.3) |
| 8                                | 66.91               |                      | 69.19               |                      |
| N <sup>9</sup> -CH <sub>3</sub>  | 30.26               | 2.98 (3H, s)         | 31.74               | 2.96 (3H, s)         |
| 10                               | 155.34              |                      | 155.88              |                      |
| N <sup>11</sup> -CH <sub>3</sub> | 27.79               | 3.20 (3H, s)         | 27.50               | 3.08 (3H, s)         |
| 12                               | 166.88              |                      | 167.16              |                      |

a) CDCl<sub>3</sub>, b) Acetone-*d*<sub>6</sub>.

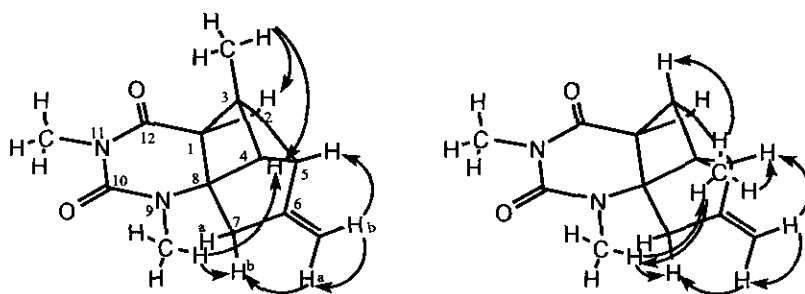
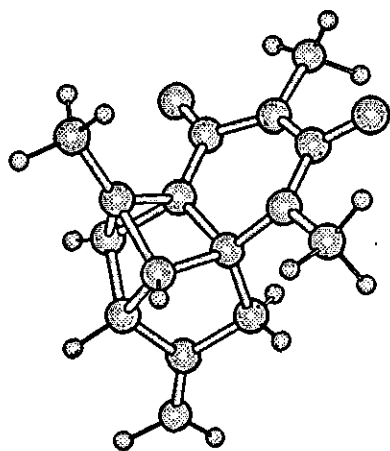
Compound(**4a**), colorless crystals, was formulated as C<sub>14</sub>H<sub>16</sub>N<sub>2</sub>O<sub>2</sub> from the high resolution mass spectrum (HRms). The <sup>1</sup>H and <sup>13</sup>C-nmr spectra including <sup>13</sup>C-<sup>1</sup>H correlation spectroscopy (<sup>13</sup>C-<sup>1</sup>H COSY) showed signals due to three methyl groups, two methylene groups, three methine groups, and six quaternary carbon atoms. The spin-spin decoupling experiments revealed the correlation between C<sup>6</sup>- and C<sup>7</sup>-methylene, and among 2-H, 4-H, and 5-H (Table 1).

Heteronuclear multiple-bond connectivity (HMBC) (Table 2) and NOE (Figure 2) experiments also provided the information to enable us to construct pentacyclic compound consisting of 3, 4, 4, and 5-membered rings. The cross peak observed between C-3 and H-7 in the HMBC spectrum was compatible with C-H long range "W" coupling.<sup>5</sup> Finally the structure of **4a** was determined by X-ray crystallographic analysis (Figure 3).

The structure of **4b** was determined by comparison with the nmr data for **4a** including <sup>13</sup>C-<sup>1</sup>H COSY (Table 1), HMBC (Table 2): In the HMBC spectrum, the cross peaks due to C-H four bonded coupling in 'W' geometry<sup>5</sup> were observed between C-6 and H-3, and C-7 and H-3. NOEs observed for C<sup>4</sup>-methyl and H-7 on irradiation at N<sup>9</sup>-methyl, and for N<sup>9</sup>-methyl, H-3, and H-5, on irradiation at C<sup>4</sup>-methyl supported the structural assignment (Figure 4).

Table 2.  $^{13}\text{C}$ - $^1\text{H}$  Long range correlations in the HMBC spectrum of **4a** and **4b**

| Carbon                   | H in <b>4a</b>                                                                         | H in <b>4b</b>                                                                     |
|--------------------------|----------------------------------------------------------------------------------------|------------------------------------------------------------------------------------|
| 1                        | $\text{C}^3\text{-CH}_3$                                                               | H-3, H-5, $\text{H}^{\text{a-7}}$ , $\text{H}^{\text{b-7}}$                        |
| 2                        | $\text{C}^3\text{-CH}_3$ , H-4                                                         | H-5                                                                                |
| 3                        | $\text{C}^3\text{-CH}_3$ , H-4, H-5, $\text{H}^{\text{a-7}}$ , $\text{H}^{\text{b-7}}$ | $\text{C}^4\text{-CH}_3$                                                           |
| 4                        | H-2, $\text{C}^3\text{-CH}_3$ , $\text{H}^{\text{a-7}}$ , $\text{H}^{\text{b-7}}$      | H-2, H-3, $\text{C}^4\text{-CH}_3$ , H-5, $\text{H}^{\text{b-7}}$                  |
| $\text{C}^4\text{-CH}_3$ |                                                                                        | H-5                                                                                |
| 5                        | $\text{C}^6\text{=CH}_2$                                                               | H-3, $\text{C}^4\text{-CH}_3$ , $\text{C}^6\text{=CH}_2$                           |
| 6                        | $\text{C}^6\text{=CH}_2$ , $\text{H}^{\text{a-7}}$ , $\text{H}^{\text{b-7}}$           | H-3, $\text{H}^{\text{a-7}}$ , $\text{H}^{\text{b-7}}$                             |
| $\text{C}^6\text{-CH}_2$ | $\text{H}^{\text{a-7}}$ , $\text{H}^{\text{b-7}}$                                      | H-5, $\text{H}^{\text{b-7}}$                                                       |
| 7                        | H-5, $\text{C}^6\text{=CH}_2$                                                          | H-3, H-5, $\text{C}^6\text{=CH}_2$                                                 |
| 8                        | H-5, $\text{H}^{\text{a-7}}$ , $\text{H}^{\text{b-7}}$                                 | $\text{C}^4\text{-CH}_3$ , H-5, $\text{H}^{\text{b-7}}$ , $\text{N}^9\text{-CH}_3$ |
| 10                       | $\text{N}^9\text{-CH}_3$ , $\text{N}^{11}\text{-CH}_3$                                 |                                                                                    |
| 12                       |                                                                                        | H-3, $\text{N}^{11}\text{-CH}_3$                                                   |

Figure 2. NOE Correlation for **4a** (left) and **4b** (right)Figure 3. X-Ray crystallography of **4a**.

The structural assignment of **5a** was made essentially on the basis of the  $^1\text{H}$ -nmr spectroscopy.  $^1\text{H}$ -Nmr spectrum exhibited signals due to two methylene groups at  $\delta$  1.55 and  $\delta$  1.71, and at  $\delta$  4.51 and  $\delta$  4.63 (Table 3). The double resonance methods revealed the correlation between H-6 and  $\text{H}^{\text{b-7}}$ , and among H-3, H-4, and H-6. NOE experiments confirmed the sites of methyl and methylene substituents (Figure 4) and the structure was supported by the HMBC spectrum (Table 4). Finally the structure of **5a**, consisting of the enantiomeric isomers (molecule A and B), was determined by X-Ray crystallographic analysis (Figure 5).

The structure of **5b** was deduced from the spectral analogy with **5a** (Table 3 and Figure 4).

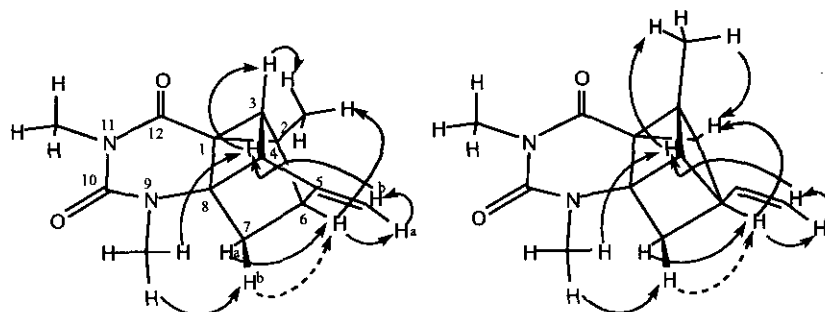


Figure 4. NOE Correlation for **5a** (left) and **5b** (right)

Table 3.  $^{13}\text{C}$ -Nmr and  $^1\text{H}$ -nmr data for **5a**<sup>a)</sup> and **5b**<sup>b)</sup>

| Position                         | <b>5a</b>            |                     | <b>5b</b>            |                         |
|----------------------------------|----------------------|---------------------|----------------------|-------------------------|
|                                  | $^{13}\text{C}$ -Nmr | $^1\text{H}$ -Nmr   | $^{13}\text{C}$ -Nmr | $^1\text{H}$ -Nmr       |
| 1                                | 48.42                |                     | 48.54                |                         |
| 2                                | 40.02                |                     | 44.35                | 2.78 (dd, 3.4, 1.0)     |
| C <sup>2</sup> -CH <sub>3</sub>  | 12.32                | 1.64 (3H, s)        |                      |                         |
| 3                                | 41.39                | 2.85 (d, 2.9)       | 31.53                |                         |
| C <sup>3</sup> -CH <sub>3</sub>  |                      |                     | 13.10                | 1.39 (3H, s)            |
| 4                                | 46.31                | 2.77 (dd, 2.9, 2.4) | 51.23                | 2.58 (br. s)            |
| 5                                | 157.56               |                     | 159.96               |                         |
| C <sup>5</sup> =CH <sup>a</sup>  | 97.96                | 4.63 (s)            | 99.54                | 4.64 (s)                |
| C <sup>5</sup> =CH <sup>b</sup>  |                      | 4.51 (s)            |                      | 4.53 (s)                |
| 6                                | 46.20                | 2.68 (t, 2.4)       | 43.16                | 2.91 (br. dd, 3.4, 2.4) |
| 7 (H <sup>a</sup> )              | 45.80                | 1.71 (dd, 9.8, 2.4) | 47.86                | 1.65 (dd, 9.3, 2.4)     |
| 7 (H <sup>b</sup> )              |                      | 1.55 (d, 9.8)       |                      | 1.58 (d, 9.3)           |
| 8                                | 63.98                |                     | 64.03                |                         |
| N <sup>9</sup> -CH <sub>3</sub>  | 27.59                | 2.84 (3H, s)        | 28.84                | 2.87 (3H, s)            |
| 10                               | 153.59               |                     | 155.96               |                         |
| N <sup>11</sup> -CH <sub>3</sub> | 30.38                | 3.20 (3H, s)        | 31.95                | 3.22 (3H, s)            |
| 12                               | 167.69               |                     | 169.75               |                         |

a) CDCl<sub>3</sub>. b) CD<sub>3</sub>OD.

Table 4.  $^{13}\text{C}$ - $^1\text{H}$  Long range correlations in the HMBC spectrum of **5a** and **5b**

| Carbon | H in <b>5a</b>                                                          | H in <b>5b</b>                                                                                  |
|--------|-------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------|
| 1      | C <sup>2</sup> -CH <sub>3</sub> , H <sup>b</sup> -7                     | C <sup>3</sup> -CH <sub>3</sub>                                                                 |
| 2      | C <sup>2</sup> -CH <sub>3</sub> , H <sup>b</sup> -7                     | C <sup>3</sup> -CH <sub>3</sub> , H <sup>a</sup> -7, H <sup>b</sup> -7                          |
| 4      | C <sup>2</sup> -CH <sub>3</sub> , C <sup>5</sup> =CH <sub>2</sub> , H-6 | H-2, H-6, C <sup>5</sup> =CH <sub>2</sub> , H <sup>a</sup> -7                                   |
| 5      | H <sup>a</sup> -7                                                       | H <sup>a</sup> -7                                                                               |
| 6      | H-4, H <sup>a</sup> -7                                                  | H-2, C <sup>3</sup> -CH <sub>3</sub> , H-4, C <sup>5</sup> =CH <sub>2</sub> , H <sup>b</sup> -7 |
| 8      | H-5, H <sup>a</sup> -7, H <sup>b</sup> -7                               | H-2, H <sup>a</sup> -7, H <sup>b</sup> -7, N <sup>9</sup> -CH <sub>3</sub>                      |
| 12     |                                                                         | N <sup>11</sup> -CH <sub>3</sub>                                                                |

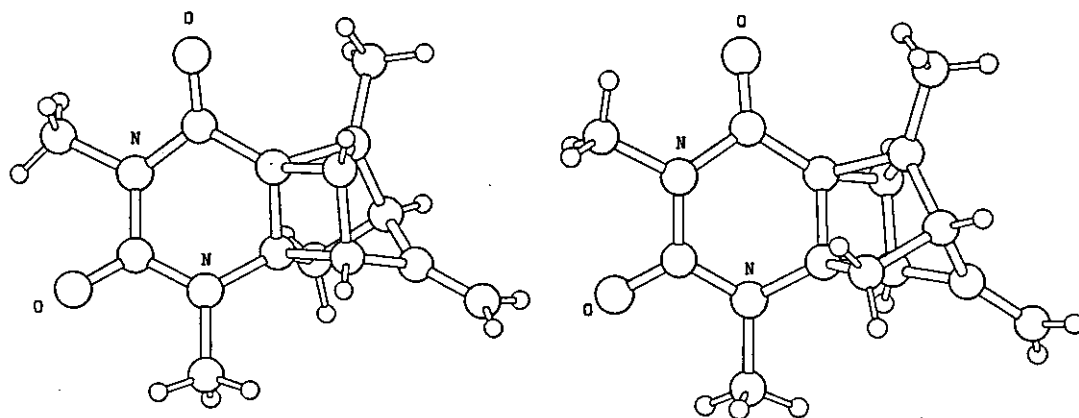
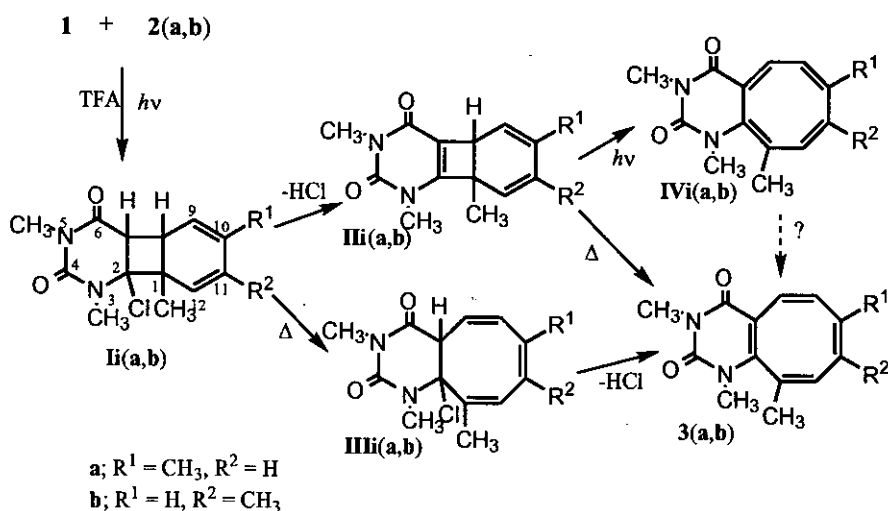


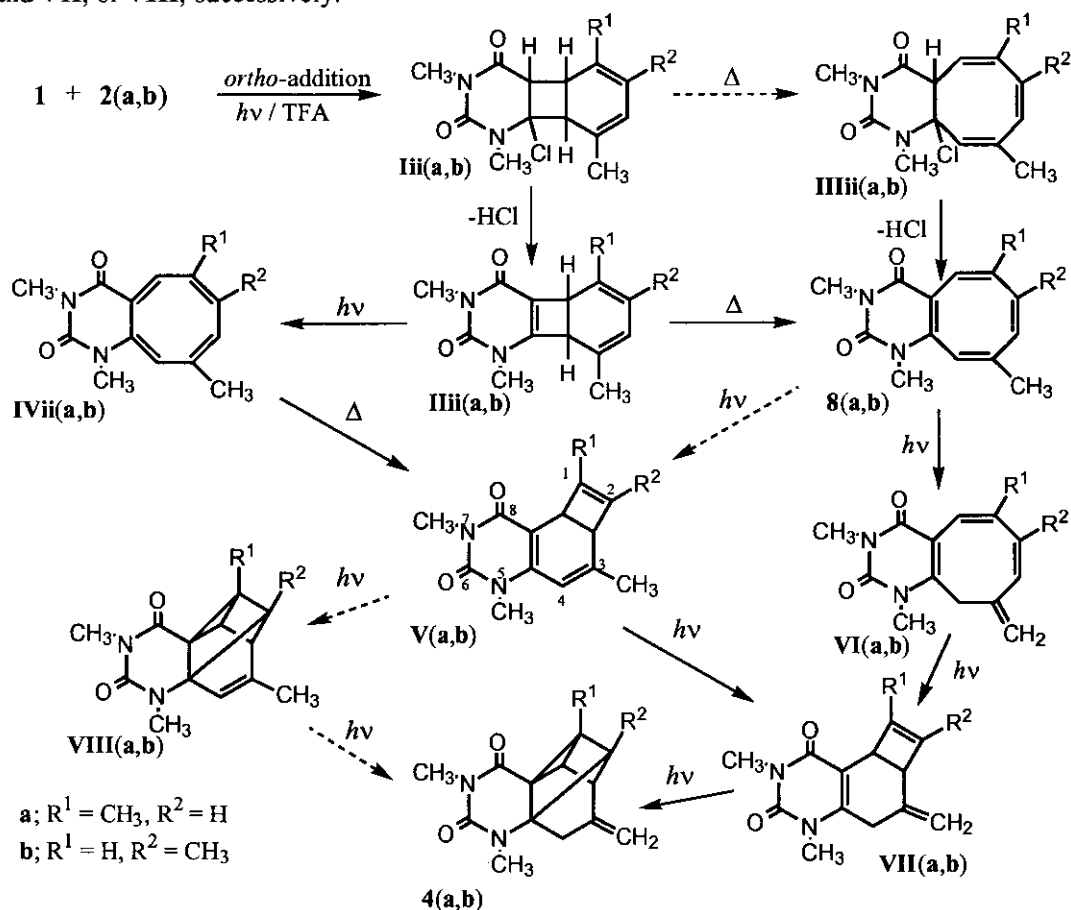
Figure 5. X-Ray crystallography of **5a**; molecule A (left) and B (right).

Interestingly each of these cycloaddition products was given as the sole regioisomer due to the methyl groups. However these cycloadducts consist of multi-step reactions involving the elimination of hydrogen chloride, causing the elucidation of the reaction pathway significantly difficult. The formation of cyclooctapyrimidine (**3**) can be explained in terms of the initial formation of the *ortho*-adduct, 1,*x*-dimethyl derivative of 2-chloro-3,5-dimethyl-3,5-diazatricyclo[6.4.0.0<sup>2,7</sup>]dodeca-9,11-diene-4,6-dione (**Iia**; *x* = 10 and **b**; *x* = 11),<sup>3</sup> wherein C-6 of the pyrimidine ring bonds to the methyl substituted aromatic carbon. The thermal disrotatory scission<sup>6</sup> of the cyclohexadiene moiety and the concomitant dehydrochlorination would lead to the formation of **3**. We have no evidence to exclude the possible pathway involving the intermediacy of **IVi** which could be derived photochemically from **IIIi** via the disrotatory cleavage<sup>6</sup> of the cyclobutene moiety (Scheme 2).



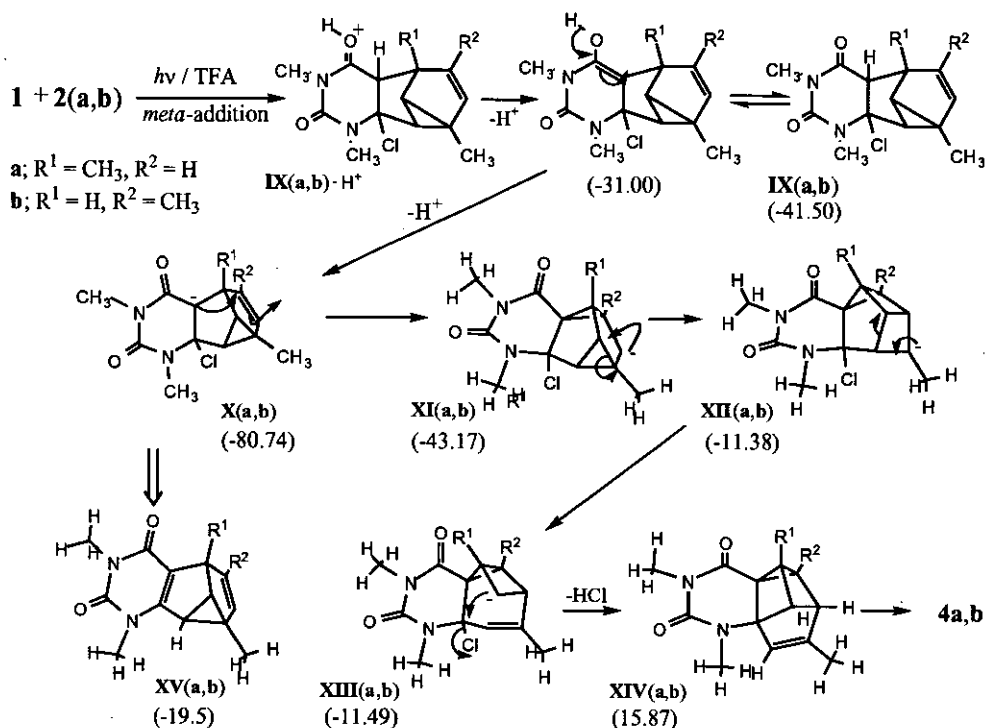
Scheme 2

The formation of the pentacyclic compound (**4**) can be explained by the mechanism involving *ortho*-cycloaddition, wherein the C-6 of pyrimidine moiety bonds to xylene (**2**) at *ortho* as to construct a 3,5-diazatricyclo[6.4.0.0<sup>2,7</sup>]dodecane ring with a methyl substituent at C-12 (**Iii**) (Scheme 3). The thermal disrotatory opening of the cyclohexadiene ring of **Iii** or the dehydrochlorinated derivative (**IIii**) would lead to the formation the 9-methylcyclooctapyrimidine derivative (**8**), resulting in the ultimate product (**4**) through **VI** and **VII**, or 3-methylene-5,7,*x*-trimethyl-2a,8b-dihydrocyclobuta[*f*]quinazoline-6,8-dione derivative **V(a,b; x = 1, 2)** and **VII**. However the latter photo-rearrangement of **8** into **V** seems less likely, since uv-irradiation of 1,3-dimethylcyclooctapyrimidine, obtained from the reaction with benzene gave no transformed product. Alternatively given that the disrotatory cleavage of the cyclobutene ring of **IIii** is effected photochemically, the resulting **IVii** would lead to the formation of **4** through the intermediacy of **V** and **VII**, or **VIII**, successively.



Scheme 3

In the preceding paper,<sup>1</sup> we proposed a mechanism involving *meta*-cycloaddition, which should have been depicted as a successive rearrangement of the anionic species initiated by the deprotonation from the *meta*-cycloadducts **IX** (Scheme 4). Although we have no experimental evidences to support or exclude the mechanism, MO calculation<sup>7</sup> showed that the rearrangement of the intermediate of **X** into **XIII** and **XIV** may be accompanied by a great loss in energy, suggesting that the formation of **4** could not be explained by the step-wise mechanism.

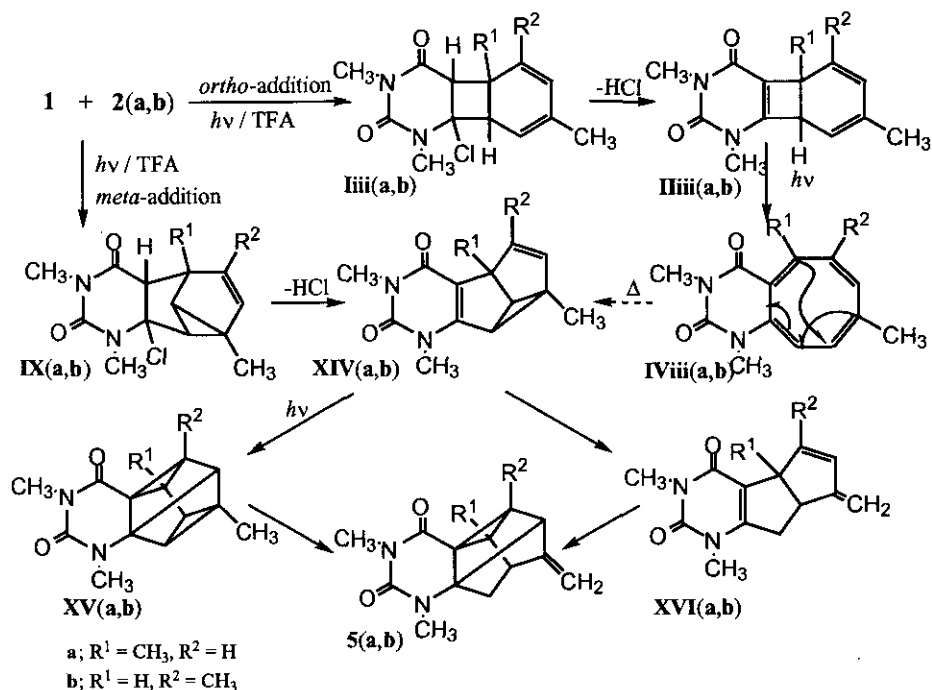


Scheme 4: The heats of formation (kcal) shown in the parentheses were calculated for the intermediates from *p*-xylene (2a) by fixing the bond lengths between C-5 of the pyrimidine ring and the carbon bearing  $R^2 = 1.54 \text{ \AA}$ .

For the explanation of the formation of diazapentacyclododecane (5), both mechanisms involving *ortho*- and *meta*-cycloaddition might be available (Scheme 5). If the reaction proceeds by way of the *ortho*-adduct with a methyl group at C-11 (Iiii), the process entails the intermediacy of IViii. Its thermal  $[\pi 4_a + \pi 2_a]$  rearrangement might lead to the formation of the key intermediate XV. However the transformation through the mechanism which is presumed to require elevated temperature seems unlikely under the present reaction condition.<sup>8</sup> Alternatively *meta*-cycloaddition is invoked. The initially formed *meta*-cycloadduct (IX) would be transformed into the ultimate product (5) through the intermediacy of XV and XVI or XVII.<sup>9</sup>

The photoreaction of 1 in *p*-xylene (2a) under similar conditions but in the absence of TFA recovered a large amount of unreacted 1 (92%) and gave barely detectable 6 (1.4%) and 3a (<0.1% on hplc), and no formation of the pentacyclic adducts (4a or 5a) was observed. The uv spectrum of 1 ( $\lambda_{\max}$  262 nm) ( $0.08 \text{ mmol} \cdot \text{dm}^{-3}$ ) shifted *ca.* 6 nm to the red in cyclohexane by the addition of TFA (9 equiv. molar). This new spectrum was insensible to the added 2a, whereas the fluorescence of this solution was quenched efficiently with 2a. Taking into consideration that the present reaction was performed in a non-polar solvent in the presence of a strong acid, it might be supposed that the present reaction may involve the initial excitation of protonated 1 in the singlet states, followed by an electron-transfer or the exciplex formation between 1 and 2.





Scheme 5

Thus the reaction pathway remains obscure, however it may be noteworthy that the present acid-catalyzed photoreaction afforded two novel pentacyclododecanes including a pyrimidine ring, whose structures were determined by X-Ray crystallographic analyses.

## EXPERIMENTAL

All melting points are uncorrected. Nmr spectra were measured with a JEOL JNM-EX400 (400 MHz) spectrometer, and  $^1\text{H}$ -nmr chemical shifts are given on the  $\delta$  (ppm) scale with tetramethylsilane as an internal standards.  $^{13}\text{C}$ -Nmr chemical shifts are recorded based on those of the signals of solvents [acetone- $d_6$  ( $\delta\text{C}29.8$ ), methanol- $d_4$  ( $\delta\text{C}49.8$ )]. Mass spectra (ms) and high resolution mass spectra (HRms) were determined on a Shimadzu GCMS 9100-MK and JEOL JMS-DX303 spectrometer with ionization potential at 70 eV. Uv and fluorescent spectra were taken on a Shimadzu UV-240 and a Shimadzu RF-540, respectively. Short-column chromatography was performed on Kieselgel Si-60 (Merck). Reverse-phase column chromatography (RP-LC) was conducted on LiChroprep RP-18 size B (Merck) with a FMI pump (Fluid Metering, Inc.). Reverse-phase high-performance liquid chromatography (RP-hplc) was performed either on a Wakosil II-5C18-100 column eluting with aqueous methanol (30-70 %) (25 cm x 4.6 mm *i.d.*, for analytical-scale) or on a Shim-pac PREP-ODS (25 cm x 20 *i.d.*, for preparative-scale) (Shimadzu), using a Shimadzu LC-6A apparatus with monitoring at 254 nm. Similarly, silica gel hplc (Si-hplc) was conducted on a Shim-pac PREP-Sil (25 cm x 20 mm *i.d.*), using the same apparatus. Uv-irradiation was carried out externally with a 500 W high-pressure mercury (Hg) lamp (Eiko-sha) in a doughnut type Pyrex vessel (500 ml), under an argon atmosphere at room temperature ( $> 300$  nm).

**Photoreaction of 6-chloro-1,3-dimethyluracil (1) in *p*-Xylene (2a)**-----A solution of **1** (349 mg, 2 mmol) and TFA (308  $\mu$ l, 4 mmol) in **2a** (400 ml) was irradiated with the 500 W high-pressure Hg lamp in a doughnut type Pyrex vessel for 20 h. The reaction mixture was concentrated *in vacuo*, and the residual oil was passed through a short column of silica gel with hexane, ether and ethyl acetate successively. The ethereal eluate was submitted to RP-LC with 38 % aqueous methanol to give **1** (108 mg, 31%), 6-methylene-3,9,11-trimethyl-9,11-diazapentacyclo[6.4.0.0<sup>1,3</sup>.0<sup>2,5</sup>.0<sup>4,8</sup>]dodecane-10,12-diones (**4a**) (30 mg, 6.1%), 6-(*p*-xylyl)uracil (**6**) (21 mg, 4.3%) and the mixture of the photoproducts. The mixture was further submitted to Si-hplc (5 % ethyl acetate-hexane) to afford 5-methylene-2,9,11-trimethyl-9,11-diazapentacyclo[6.4.0.0<sup>1,3</sup>.0<sup>2,6</sup>.0<sup>4,8</sup>]dodecane-10,12-dione (**5a**) (9.6 mg, 2.0%), 1,3,7,10-tetramethylcyclooctapyrimidine-2,4-dione (**3a**) (56 mg, 11.5%), and 1,3-dimethyl-6-(4-methylbenzyl)uracil (**7**) (9.2 mg, 1.9%). 6-(*p*-Xylyl)uracil (**6**) was identified with authentic sample on the bases of comparison of the <sup>1</sup>H-nmr and ms spectra.

1,3,7,10-tetramethylcyclooctapyrimidine-2,4-dione (**3a**): Colorless crystals, mp 104-105°C (recrystallized from 2-propanol). <sup>1</sup>H-Nmr (acetone-*d*<sub>6</sub>)  $\delta$ : 1.70 (3H, m, C<sup>7</sup>-CH<sub>3</sub>), 1.93 (3H, t, *J* = 1.5 Hz, C<sup>10</sup>-CH<sub>3</sub>), 3.22 (3H, s, N<sup>3</sup>-CH<sub>3</sub>), 3.27 (3H, s, N<sup>1</sup>-CH<sub>3</sub>), 5.83 (1H, dd, *J* = 3.4, 1.0 Hz, H-8), 5.93 (1H, d, *J* = 11.2 Hz, H-6), 6.04 (1H, d, *J* = 3.4 Hz, H-9), 6.18 (1H, dd, *J* = 11.2, 1.0 Hz, H-5). Ms *m/z* (%): 244 (M<sup>+</sup>, 100), 229 (30). Anal. Calcd for C<sub>14</sub>H<sub>16</sub>N<sub>2</sub>O<sub>2</sub>: C, 68.83; H, 6.60; N, 11.47. Found: C, 68.80; H, 6.51; N, 11.45.

6-methylene-3,9,11-trimethyl-9,11-diazapentacyclo[6.4.0.0<sup>1,3</sup>.0<sup>2,5</sup>.0<sup>4,8</sup>]dodecane-10,12-diones (**4a**): Colorless crystals, mp 106-107 °C, (recrystallized from ether). Ms *m/z* (%): 244 (M<sup>+</sup>, 28), 243 (100), 229 (63), 204 (94), 187 (18), 172 (20), 158 (37), 147 (80), 144 (33). HR-ms: Anal. Calcd for C<sub>14</sub>H<sub>16</sub>N<sub>2</sub>O<sub>2</sub>: 244.1211. Found: 244.1212. 5-methylene-2,9,11-trimethyl-9,11-diazapentacyclo[6.4.0.0<sup>1,3</sup>.0<sup>2,6</sup>.0<sup>4,8</sup>]dodecane-10,12-diones (**5a**): Colorless crystals, mp 97.5-98.5 °C, recrystallized from hexane. Ms *m/z* (%): 244 (M<sup>+</sup>, 9), 243 (14), 229 (100), 173 (9), 172 (64), 144 (25). HRms: Anal. Calcd for C<sub>14</sub>H<sub>16</sub>N<sub>2</sub>O<sub>2</sub>: 244.1211. Found: 244.1188.

1,3-dimethyl-6-(4-methylbenzyl)uracil (**7**): Pale yellow crystals, mp 108-109°C, recrystallized from benzene-hexane. <sup>1</sup>H-Nmr (CDCl<sub>3</sub>)  $\delta$ : 2.35 (3H, s, C-CH<sub>3</sub>), 3.32 (3H, s, N-CH<sub>3</sub>), 3.35 (3H, s, N-CH<sub>3</sub>), 3.78 (2H, s, CH<sub>2</sub>), 5.55 (1H, s, H-5), 7.06 (2H, d, *J* = 8.1 Hz, aromatic H), 7.16 (2H, d, *J* = 8.1 Hz, aromatic H). Ms *m/z* (%): 245, 12), 244 (M<sup>+</sup>, 58), 227 (14), 130 (12), 105 (67), 82 (100). HRms: Anal. Calcd for C<sub>14</sub>H<sub>16</sub>N<sub>2</sub>O<sub>2</sub>: 244.1211. Found: 244.1230.

**Photoreaction of 1 in *m*-Xylene (2b)**-----Photoreaction was carried out under conditions describes above. The reaction mixture was passed through a short column of silica gel. The ethereal eluate was submitted to RP-LC with 38 % aqueous methanol to give **4b** (13 mg, 2.7 %), **5b** (5.4 mg, 1.1%), **3b** (19.5 mg, 4.0%) and **6b** (12 mg, 2.5%), together with the recovered **1** (199 mg, 57%).

1,3,8,10-tetramethylcyclooctapyrimidine-2,4-dione (**3b**): Colorless crystals, mp 139-141°C (recrystallized from 2-propanol). <sup>1</sup>H-Nmr (CDCl<sub>3</sub>)  $\delta$ : 1.82 (3H, br s, C<sup>8</sup>-CH<sub>3</sub>), 1.93 (3H, d, *J* = 1.5 Hz, C<sup>10</sup>-CH<sub>3</sub>), 3.32 (3H, s, N<sup>1</sup>-CH<sub>3</sub>), 3.35 (3H, s, N<sup>3</sup>-CH<sub>3</sub>), 5.70 (1H, d, *J* = 4.0 Hz, H-7), 5.97 (1H, ddd, *J* = 1.5, 1.5, 1.1 Hz, H-9), 6.02 (1H, dddd, *J* = 11.4, 4.0, 1.5, 1.1 Hz, H-6), 6.26 (1H, d, *J* = 11.4, H-5). Ms *m/z* (%) 245 (21), 244 (M<sup>+</sup>, 100), 229 (29), 172 (44), 159 (25), 158 (21), 144 (30). Anal. Calcd for C<sub>14</sub>H<sub>16</sub>N<sub>2</sub>O<sub>2</sub>: C, 68.83; H, 6.60; N, 11.47. Found: C, 68.80; H, 6.51; N, 11.45.

6-methylene-4,9,11-trimethyl-9,11-diazapentacyclo[6.4.0.0<sup>1,3</sup>.0<sup>2,5</sup>.0<sup>4,8</sup>]dodecane-10,12-diones (**4b**): Colorless crystals, mp 132-134 °C (recrystallized from benzene-hexane). Ms *m/z* (%): 244 (*M*<sup>+</sup>, 43), 243 (100), 229 (54), 204 (36), 187 (26), 186 (14), 172 (22), 159 (31), 158 (49), 147 (38), 144 (38). HRms: Anal. Calcd for C<sub>14</sub>H<sub>16</sub>N<sub>2</sub>O<sub>2</sub>: 244.1235. Found: 244.1212.

5-methylene-3,9,11-trimethyl-9,11-diazapentacyclo[6.4.0.0<sup>1,3</sup>.0<sup>2,6</sup>.0<sup>4,8</sup>]dodecane-10,12-diones (**5b**): Colorless oil. Ms *m/z* (%): 244 (*M*<sup>+</sup>, 54), 243 (51), 229 (100), 186(23), 172 (66), 158 (30), 144 (32). HRms: Calcd for C<sub>14</sub>H<sub>16</sub>N<sub>2</sub>O<sub>2</sub>: 244.1211. Anal. Found: 244.1211.

1,3-dimethyl-6-(2,4-dimethylphenyl)uracil (**7b**): Colorless oil. Ms *m/z* (%): 245 (31), 244 (*M*<sup>+</sup>, 88), 243 (39), 229 (100), 172 (63), 159 (43), 158 (66). <sup>1</sup>H-Nmr (CDCl<sub>3</sub>)δ: 2.24 (3H, s, C-CH<sub>3</sub>), 2.37 (3H, s, C-CH<sub>3</sub>), 3.07 (3H, s, N-CH<sub>3</sub>), 3.41 (3H, s, N-CH<sub>3</sub>), 5.63 (1H, s, H-5), 7.03 (1H, d, *J* = 7.8 Hz, H-5'), 7.16 (1H, d, *J* = 7.8 Hz, H-6'), 7.11 (1H, s, H-3'). HRms: Anal. Calcd for C<sub>14</sub>H<sub>16</sub>N<sub>2</sub>O<sub>2</sub>: 244.1211. Found: 244.1186.

**X-Ray Crystallography of 4a** ---- The diffraction experiment was carried out using a colorless transparent prism with dimension of 0.45 x 0.35 x 0.35 mm. The diffract meter AFC/5 (RIGAKU) was used with graphite-monochromated CuKα radiation (λ = 1.5418 Å). The unit cell dimensions were determined from angular setting of 20 reflections (2θ values in the range of 35-60°), affording the following crystal data: C<sub>14</sub>H<sub>16</sub>N<sub>2</sub>O<sub>2</sub>, Mr = 244.29. *a* = 15.089(3), *b* = 14.652(2), *c* = 7.672(2) Å, β = 131.24(1)°, *U* = 1275.3(5) Å<sup>3</sup>, monoclinic, P2<sub>1</sub>/*a*, *Z* = 4, *D<sub>x</sub>* = 1.27 g/cm<sup>3</sup>, *F*(000) = 520, μ(CuKα) = 7.08 cm<sup>-1</sup>. 1896 unique reflections (2θ ≤ 120°) were measured, of which 1601 with |*F<sub>o</sub>*| ≥ 2.67 σ (*F<sub>o</sub>*) were considered as observed. No absorption corrections were applied.

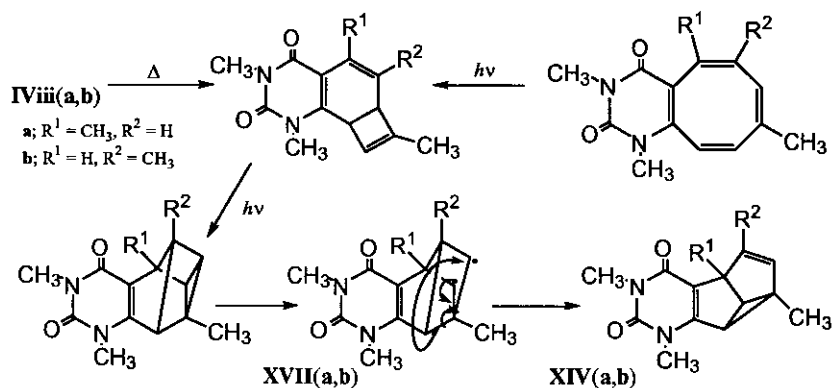
The structure was solved by a direct method using MULTAN 80<sup>10</sup> and difference Fourier method. The refinement of atomic parameters were carried out using block diagonal least-squares method with anisotropic temperature factors. Eight hydrogen atoms were located on the difference-Fourier maps and refined with isotropic temperature factors. The positions of the residual hydrogen atoms were assumed in the geometrically and fixed. Throughout the refinement, the function Σ w(|*F<sub>o</sub>*| - |*F<sub>c</sub>*|)<sup>2</sup> was minimized. The atomic scattering factors were taken from International Tables for X-Ray crystallography.<sup>11</sup> The final *R* factor is 0.067.

**X-Ray Crystallography of 5a** ---- The diffraction experiment was carried out using a colorless transparent prism with dimension of 0.2 x 0.2 x 0.1 mm. The diffract meter AFC/5 (RIGAKU) was used with graphite-monochromated CuKα radiation (λ = 1.5418 Å). The unit cell dimensions were determined from angular setting of 25 reflections (2θ values in the range of 70-90°), affording the following crystal data: C<sub>14</sub>H<sub>16</sub>N<sub>2</sub>O<sub>2</sub>, Mr = 244.29. *a* = 9.756(2), *b* = 14.898(2), *c* = 8.906(1) Å, β = 94.33(1)°, *U* = 1265.6(3) Å<sup>3</sup>, triclinic, P  $\bar{1}$ , *Z* = 4, *D<sub>x</sub>* = 1.28 g/cm<sup>3</sup>, *F*(000) = μ(CuKα) = 7.04 cm<sup>-1</sup>. 3056 independent reflections (2θ ≤ 130°) were measured. The structure was solved by a direct method using SHELXS-86<sup>12</sup> and difference Fourier method. The refinement of atomic parameters were carried out using full-matrix least-squares method(SHELXL-93)<sup>13</sup> with anisotropic temperature factors. The final *R* factor is 0.063.

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Scheme 6

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