

## *N*-메틸루티돈에 대한 광화학적 연구

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## Photochemical Studies of *N*-Methyllutidone

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**요약.** 피리미딘 염기의 모델 화합물인 *N*-메틸루티돈을 벤조페논과 같이 아세토니트릴에 녹여 313 nm 자외선으로 조사한 결과 네가지 생성물이 생겼다. 이중 세가지를 확인한 결과 *N*-(벤즈히드릴메틸)루티돈, 루티돈, *N*-(4-벤조일벤질) 루티돈임을 알았으며 이들의 양자수득율은 각각  $5.07 \times 10^{-3}$ ,  $1.84 \times 10^{-3}$ ,  $1.43 \times 10^{-3}$  이었다.

**ABSTRACT.** A model compound for pyrimidine bases, *N*-methyllutidone, was irradiated with benzophenone in acetonitrile at 313 nm. Three of the four photoproducts were isolated by column chromatography and characterized. *N*-(Benzhydrylmethyl) lutidone, lutidone, and *N*-(4-benzoylbenzyl) lutidone were formed with quantum yields of  $5.07 \times 10^{-3}$ ,  $1.84 \times 10^{-3}$ , and  $1.43 \times 10^{-3}$  respectively.

### INTRODUCTION

Pyrimidine bases undergo photohydration through excited singlet state and photocyclodimerization through excited triplet state in dilute aqueous solutions<sup>1</sup>. A model compound for pyrimidine bases, *N*-methyllutidone, also undergoes photohydration reaction at  $\alpha$ -position to nitrogen when a dilute aqueous solution ( $<10^{-4} M$ ) is irradiated with a germicidal lamp in a quartz tube<sup>2</sup>. However, no cyclobutane photodimer of *N*-methyllutidone is formed in contrast to thymine or uracil when concentrated aqueous or acetonitrile solution of the compound is irradiated.

The dimerization of thymine derivatives have been studied using triplet sensitizers<sup>3,4</sup>. Four isomeric photocyclodimers of thymine derivatives are formed when the reaction is sensitized with acetone or acetophenone<sup>5</sup>. The quantum efficiencies and relative yields of four dimers vary as the substitution pattern on nitrogens in pyrimidine ring varies. This is expected since tautomeric form of pyrimidines change as *N*-substitution pattern is varied. This will cause the energy level scheme of these tautomers different from each other and consequently the reactivity of triplet states of these tautomers are expected to be different. *N*-Methyllutidone exists in only one tautomeric form and its photochemical beha-

rior is studied by irradiating the compound in acetonitrile with benzophenone.

## EXPERIMENTAL

**Synthesis of *N*-Methylrutidone.** *N*-methylrutidone was synthesized from dehydroacetic acid and methylamine as reported<sup>6</sup>. m. p 248.0~249.0°C (lit. 247~248). nmr<sup>7</sup> and ir<sup>8</sup> data matched the literature values exactly.  $\lambda_{\max}^{H_2O}$  258.0 nm (15,000), 308.0 nm (3.1).

**Irradiation of the Sample.** A Hanovia 450 W medium pressure mercury arc lamp was used as light sources. *N*-methylrutidone (0.05 *M*) and benzophenone (0.15 *M*) solution in purified acetonitrile<sup>9</sup> turned pale yellow when the solution is irradiated through pyrex filter for 50 hours.

**Analysis of Products.** Irradiated samples were analyzed by thin layer chromatogram of silica gel (Wako gel B-5, 0.25 mm thick) utilizing methanol-ether (1:1 v/v) as a developing solvent and iodine vapor as visualization agent. Four products were observed with  $R_f$  values of 0.75, 0.67, 0.59, and 0.50 respectively. Three of the four products were isolated by silica gel column (Wako gel C-200, Wako Chemical Industries, Inc.) chromatography. Benzophenone was eluted first with ether. The polarity of eluting solvent was varied gradually by adding methanol and TLC was used for monitoring. These products were characterized by Perkin-Elmer 267 infrared, Cary 17 UV-VIS spectrophotometers, Varian T-60A nmr spectrometer, Finnigan 1015 mass spectrometer, and by the comparison with authentic samples.

**Quantum Yield Measurements.** A solution of 3mL of *N*-methylrutidone (0.05 *M*) with benzophenone (0.15 *M*) in acetonitrile was put into a Pyrex ampoule and degassed by three freeze-pump-thaw cycles with cooling in liquid nitrogen and then sealed. Thus prepared samples were irradiated in a "merry-go-round" unit. A

Corning glass filter #7-54 and a solution filter of  $2.5 \times 10^{-3}$  *M* potassium dichromate in 1% sodium carbonate aqueous solution were used to get a monochromatic light of 313.0 nm. The light intensity was measured by ferrioxalate actinometry<sup>10</sup> and the amounts of photoproducts were monitored by TLC and UV-VIS spectrophotometer.

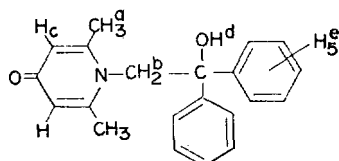
## RESULTS AND DISCUSSION

*N*-Methylrutidone-benzophenone solution in acetonitrile was irradiated in a Pyrex vessel ( $\lambda > 300\text{nm}$ ) and the reaction is monitored by thin layer chromatography. Four products were observed with  $R_f$  values of 0.75 (compound A), 0.67 (B), 0.59 (C), and 0.50 (D) respectively. Visualization in iodine chamber showed a faint spot for compound B indicating a trace amount of B in photoproducts. No product was observed when *N*-methylrutidone alone in acetonitrile was irradiated in a Pyrex vessel.

The products A, C, and D were separated by column chromatography and characterized by nmr, ir, uv-vis., and mass spectra.

**Compound A.** Compound A was formed with quantum yield of  $5.07 \times 10^{-3}$  and has a m. p of 238~239°C. Infrared spectrum in potassium bromide pellet showed a sharp band at  $3,640\text{cm}^{-1}$  indicating the presence of hydroxyl group. The rest of the spectrum resembles that of *N*-methylrutidone except  $\delta_{C-H}$  of  $>N-CH_3$  group.  $\delta_{C-H}$  at  $1,400\text{cm}^{-1}$  is missing and a new band at  $1,475\text{cm}^{-1}$  which can be regarded as  $\delta_{C-H}$  of  $>N-CH_2-$  group appeared. Proton nmr spectrum in DMSO- $d_6$  solvent showed six singlet peaks at 1.83 ( $H_a$ , 6H), 4.5 ( $H_b$ , 2H), 5.78 ( $H_c$ , 2H), 6.3 ( $H_d$ , 1H), and 7.3 ( $H_e$ , 10H) ppm ( $\delta$ ). Ten protons at 7.3ppm indicate the presence of two identical, monosubstituted benzene rings and singlet at 6.3ppm indicates hydroxyl proton. From these data, *N*-(benzhydrylmethyl)

lutidone structure can be postulated for compound A.



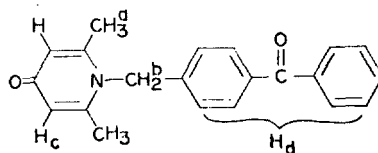
Mass spectrum was taken at 70 eV. No molecular ion peak was observed but peaks of  $m/e$  at 182 (benzophenone), 183 ( $\phi-\overset{\text{OH}}{\underset{+}{\text{C}}}-\phi$ ), 137 (lutidone), 122 ( $\text{O}=\text{C}(\text{CH}_3)_2\text{N}^+$ ), 105 (benzoyl cation), and 77 (phenyl group) are consistent with the structure proposed. Compound A showed  $\lambda_{\text{max}}$  at 266 nm ( $\epsilon 2.36 \times 10^4$ ) in methanol which is about same as ( $\pi \rightarrow \pi^*$ ) transition in *N*-methyllutidone.

**Compound C.** Compound C was obtained with a quantum yield of  $1.84 \times 10^{-3}$ . Infrared spectrum is very similar to that of *N*-methyllutidone except 3,350  $\text{cm}^{-1}$  band indicating the presence of N—H group. Proton nmr spectrum in pyridine- $d_5$  shows a singlet at 6.40 (2H) ppm, a singlet at 2.18 (6H) ppm, and a broad band between 5.1 and 5.7 ppm (1H). Lutidone can be deduced from the data for the structure of compound C. The UV spectrum in methanol shows  $\lambda_{\text{max}}$  at 258 nm which is consistent with that of lutidone. The infrared and nmr spectra of authentic sample synthesized match exactly those of compound C and  $R_f$  values on TLC are also consistent.

**Compound D.** Compound D is formed with a quantum yield of  $1.43 \times 10^{-3}$  and melts at 151 ~ 153 °C.

Infrared spectrum in potassium bromide pellet shows 1,625 and 1,660  $\text{cm}^{-1}$  bands indicating two carbonyl groups in the molecule. The  $\delta_{\text{C-H}}$  band of  $>\text{N}-\text{CH}_3$  group at 1,400  $\text{cm}^{-1}$  is also missing and a new band at 1,470  $\text{cm}^{-1}$  correspond-

ing to  $\delta_{\text{C-H}}$  of  $>\text{N}-\text{CH}_2-$  group appeared just like in compound A. Bands at 700 and 730  $\text{cm}^{-1}$  indicate the presence of a phenyl ring. Proton nmr spectrum in  $\text{CDCl}_3$  solvent is shown in Fig 1. The spectrum shows singlet peaks at 2.3 ( $\text{H}_a$ , 6H), 5.2 ( $\text{H}_b$ , 2H), and 6.25 ( $\text{H}_c$ , 2H) ppm and a multiplet at 6.9~7.8 ppm ( $\text{H}_d$ , 9H). When the multiplet region of the spectrum is expanded as shown in Fig 1, two doublet of AB system with a coupling constant of 8 Hz were observed indicating a para-substituted phenyl ring. From these data, *N*-(4-benzoylbenzyl)lutidone is proposed for the structure of compound D.



Mass spectrum shows the parent peak of  $m/e$  317 which is the molecular weight of *N*-(4-benzoylbenzyl)lutidone. The fragmentation pattern indicates the presence of benzoylbenzyl group ( $m/e$  195), lutidone ( $m/e$  123), benzoyl ( $m/e$  105), and phenyl group ( $m/e$  77).

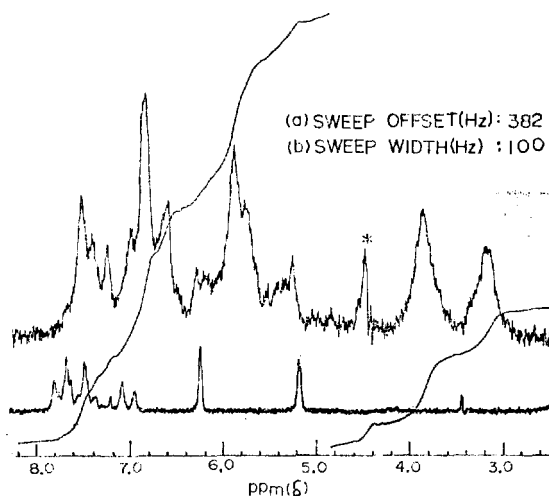


Fig. 1. Proton NMR Spectrum of compound D in  $\text{CDCl}_3$ .

Ultraviolet and visible spectra show ( $n, \pi^*$ ) band of benzophenone at 330 nm ( $\epsilon$  201) and ( $\pi, \pi^*$ ) band at 264 nm ( $\epsilon$   $3.28 \times 10^4$ ) as expected for compound D, and the proposed structure is proven right.

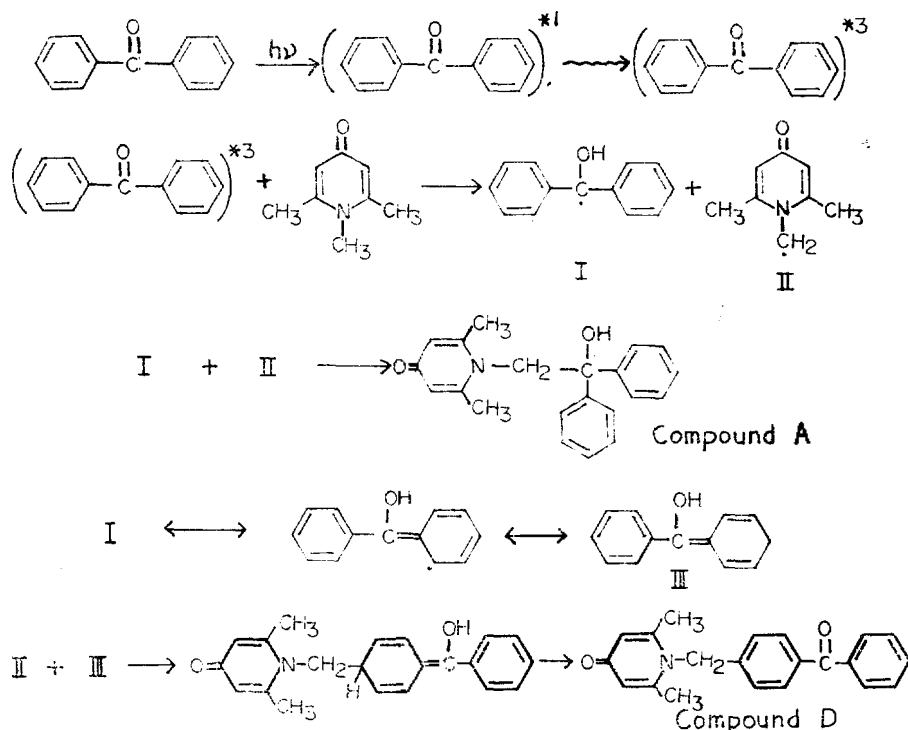
### REACTION MECHANISMS

Benzophenone triplet energy is known to be 68.5 kcal/mole and it was expected to transfer its triplet energy to *N*-methyllutidone to induce  $C_4$ -cyclodimerization of lutidone. However, no lutidone dimer was observed and compound A and D are formed instead. They are very likely to be derived from benzophenone triplet itself. When benzophenone is irradiated in isopropanol or benzhydrol, benzopinacol is formed through benzophenone triplet state<sup>11,12</sup>. When *N*-methyl-lutidone-benzophenone solution in acetonitrile is irradiated, only benzophenone absorbs light and an efficient intersystem crossing from benzo-

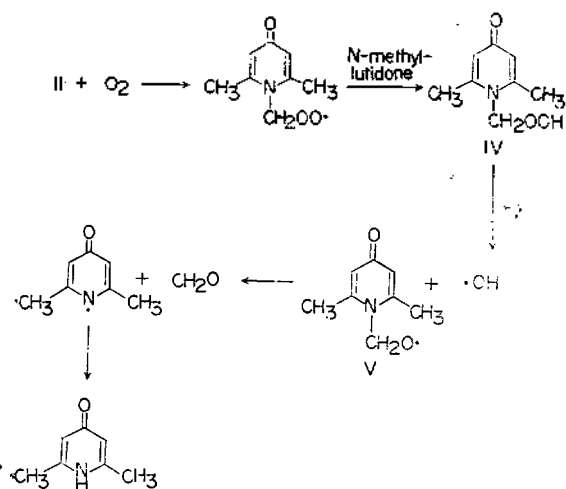
phenone singlet excited state to triplet state affords benzophenone triplet state which abstracts most labile hydrogen in the system, i. e.,  $N-CH_3$  hydrogens of lutidone<sup>13</sup> forming radicals I and II as shown below. Compound A is formed by coupling of radical I and II.

The free radical I is in resonance with radical III and coupling of II and III followed by tautomerization yields compound D. The same type of photoreduction product is formed when benzophenone is irradiated in isopropanol<sup>14</sup>.

Lutidone can be formed from radical II by oxidation as shown below. Oxidation of radical II by molecular oxygen will yield peroxy radical and this radical in turn will abstract a hydrogen from *N*-methyllutidone to form *N*-hydroperoxy-methyllutidone IV. The compound IV is then photolyzed to yield hydroxyl radical and radical V. Radical V will give formaldehyde and lutidone radical and this lutidone radical will ab-



tact hydrogen from *N*-methylrutidone or formaldehyde to give lutidone. This oxidation mechanism is confirmed by observing a drastic decrease in the yield of lutidone when the solution is degassed by freeze-pump-thaw cycles prior to irradiation.



It is interesting to observe no triplet energy transfer from benzophenone to *N*-methylrutidone. Apparently the triplet state of *N*-methylrutidone is lying higher than that of benzophenone and phosphorescence of *N*-methylrutidone is being studied in our laboratory.

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