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4. Although the role of pyridine in this reduction is not clear, we believe that pyridine behaves as a coordinator to the boron atom of **1** resulted in a borane-pyridine complex which inhibits the hydride attact from LAH to the carbonyl carbon.

Evidence of Radical Ion Pair for Singlet Oxygen Reaction of Bilirubin and Related Oxopyrromethenes. Oxidation Potential of Bilirubin and Related Oxopyrromethenes

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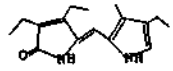
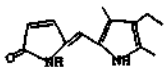
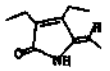
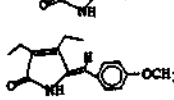
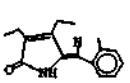
The phototherapy for treating neonatal jaundice is used since the caused bilirubin IX-α (BR) in the human body is destroyed by light illumination[1-3]. BR is destroyed by photoreaction under aerobic or anaerobic conditions. Photooxygention of BR in the presence of a sensitizer, rose bengal, gave methylvinyl maleimide, hematinic acid and two propendyopents[4-5]. The oxomonopyrromethenes (**6**, **7**, **8**, see table 1) resisted dye-sensitized photooxygenation; whereas oxodipyrromethenes (**1**, **2**, see Table 1) and mesobilirubin (MBR) reacted with singlet oxygen ($^1O_2$) to give products from cleavage of exocyclic enamide double bonds[6]. Kinetic study showed that highly substituted oxodipyrromethenes are more reactive toward $^1O_2$[6]. Thus radical ion mechanism[6] was suggested for singlet oxygen reaction of BR and BR-related compounds.

In this work singlet oxygen reaction rate ($^1O_2$ generated by the thermal method) and oxidation potential of BR and BR-related enamines (mainly oxopyrromethenes) were measured as evidences for radical ion pair mechanism in the singlet oxygen reaction of the enamine derivatives (BR and BR-related substrates).

Khan and Kasha[7] reported that $^1O_2$ is generated by reaction of NaOCl with H_2O_2. BR and BR-related substrates (1 mg) was dissolved in 5 m*l* of methanol. The solution (1 m*l*) was taken in 3 m*l* UV cuvette and 1 m*l* of 30%-H_2O_2 and 0.2 m*l* of NaOCl solution (effective chlorine 10%) were added. The percent change of the absorbance of BR and BR-related substrates were measured within 3 min reaction time. They are summarized in Table 1. MBR, BR and oxodipyrromethenes (**1**,**2**) are reactive; whereas BV and oxomonopyromethenes (**6**,**7**,**8**) are unreactive toward $^1O_2$ generated chemically. For comparison, K_R values, reaction rate constant of enamine substrates from ref. 6 was also given in the table. The same reactivity tendency of BR and BR-related substrates is shown for $^1O_2$ generated photochemically or thermally.

Cyclic voltammograms of BR and BR-related substrates were measured within 0~+1.2 volt *vs.* Saturated Calomel Electrode (SCE) with polarographic analyzer and universal

Table 1. Reaction Rate Constants and Percent Absorbance Changes of Bilirubin and Its Model Compounds with $^1O_2$ Generated by Photochemical and Thermal Methods, Respectively. Oxidation Potential of Bilirubin and Its Model Compounds

Bilirubin and its model compounds	% change of absorbance in 3 min[b]	K_R ($\times 10^9$ $M^{-1}S^{-1}$)[c]	Oxidation potential *vs.* S.C.E.(volt)
 1	37.2%	1.4 1.0[a]	0.24
 2	43.9%	0.1	0.32
Mesobilirubin IX-a (MBR) 3	60.8%	0.79[a]	0.24, 0.37 0.60
Bilirubin IX-a (BR) 4	33.1%[d]	0.28[a]	0.32, 0.44 0.64
Biliverdin IX-a (BV) 5	0%	0.0024	0.34, 0.60
 6	0%	0	0.80
 7	0%	0	0.98, 1.06
 8	0%	0	1.07, 1.12

[a] With 0.2% vol. conc. NH_4OH. [b] In methanol. [c] Taken from ref. 6. in methanol.

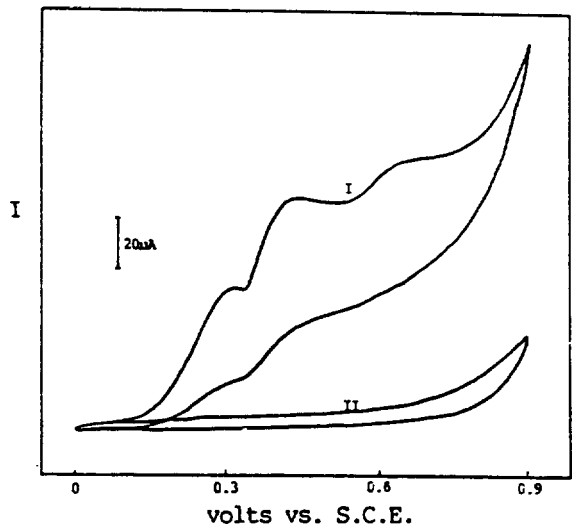


Figure 1. The cyclic voltammogram of 4.5×10^{-4}M bilirubin(I) and residual current(II) in 0.1M tetraethylammonium perchlorate in DMF solution at 25 °C. Voltage scan rate; 2 mV /sec.

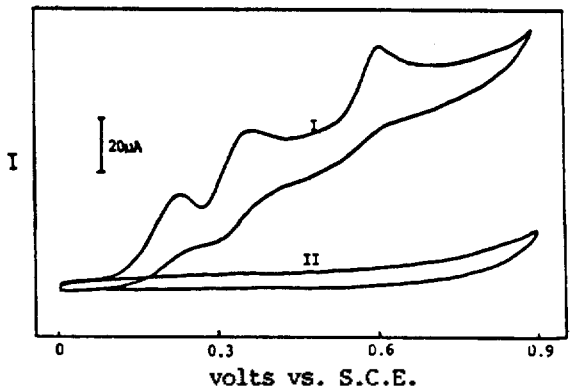
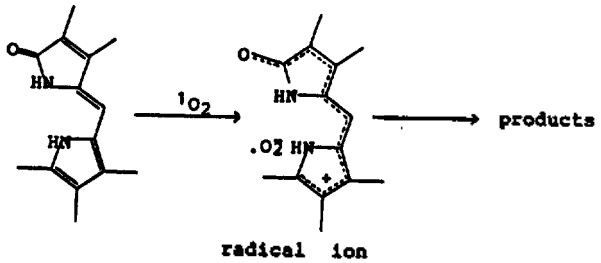


Figure 2. The cyclic voltammogram of 4.5×10^{-4}M meso-bilirubin(I) and residual current(II) in 0.1M tetraethylammonium perchlorate in DMF solution at 25 °C. Voltage scan rate; 2 mV /sec.

programmer as shown in Figure 1 and 2. In Figure 1, the cyclic voltammogram of 4.5×10^{-4}M BR(I) and residual current(II) in 0.1M tetraethylammonium perchlorate (supporting electrolyte) in DMF solution at 25 °C is shown. The oxidation peak potentials ot BR, which are 0.32, 0.44 and 0.64 volt *vs.* SCE respectively could be observed. It is an irreversible wave since no re-reduction wave is shown. These results are different from that of Norman[8] in DMF solvent (0.6 and 0.8 volt *vs.* SCE), but the same as that of Longhi[9] (0.35-0.40, 0.58-0.60, and 0.72-0.73 volt *vs.* SCE). The small differences in the oxidation peak potentials are due to the different working electrode (Glassy Carbon electrode in this work). The cyclic voltammogram of MBR is shown in Figure 2. Three oxidation peaks of MBR (0.24, 0.37, and 0.60 volt *vs.* SCE) which are lower oxidation potentials than BR were observed in Figure 2. The oxidation potential of BR and BR-related substrates are given in Table 1. The more reactive oxodipyrromethenes (1,2), MBR, and BR toward $^1O_2$ have low oxidation potentials. The easier MBR and oxodipyrromethenes are oxidized, the easier cation radicals are formed with $^1O_2$ (see Scheme 1). Electron poor enamides (6, 7 and 8) which are unreactive toward $^1O_2$ have high oxidation potential. The pyrrolinone moiety of the oxomonopyrromethenes destabilizes the intermediate, cation radical in the $^1O_2$ reaction.



Scheme 1

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