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Enhancement of Efficiency in Solar Energy Utilization by Mixed Photosensitizers

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The solar radiation reaching the earth surface consists of light with a wide range of wavelengths, *i.e.,* the light distributes from near ultraviolet to infrared region. To use the solar energy efficiently, a photosensitizer which absorbs most of the solar radiation, is required. This requirement will be satisfied by using a combination of various photosensitizers with the absorption spectrum from near ultraviolet to infrared region.

In this communication, a trial was carried out by methyl viologen photoreduction with the system containing various photosensitizers. As the reduced form of methyl viologen has a sufficient redox potential for the reduction of water, photo-induced reduction of methyl viologen is one of the essential processes in the photochemical decomposition of water.

All reagents were obtained from commercial sources and were of the highest purity available. Tris(4,7-dimethyl-10-phenanthroline)ruthenium (Ru(dime-phen)$_3^{2+}$) and zinc(II) tetraphenylporphyrin (Zn–TPP) were synthesized according to the literature [1, 2]. As Zn–TPP and hematoporphyrin (Hm) do not dissolve in water, they were used as micelles by using the surfactant cetyldimethylbenzylammonium hydroxide (CDBAH).

A typical experiment was performed as follows under anaerobic conditions at 30 °C. A reaction mixture (6 cm^3) containing photosensitizer, methyl viologen and mercaptoethanol as a reducing agent in 0.02 mol dm^{-3} phosphate buffer (pH 7.0) solution was irradiated by a 150 W tungsten lamp. The light of wavelength less than 390 nm was cut off by a Toshiba UV-filter.

Photoreduction of methyl viologen by irradiation of the system containing various photosensitizers in the presence of mercaptoethanol was carried out. The dependence of the initial rate on the concentration of photosensitizers is shown in Fig. 1.

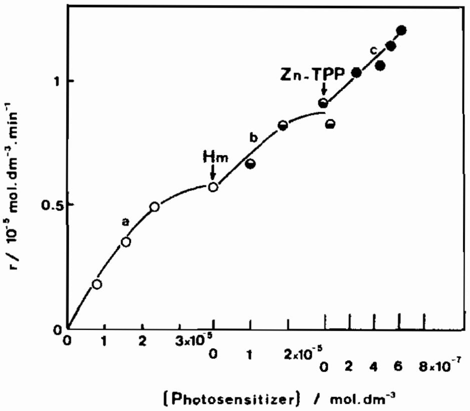

Fig. 1. Effect of the combination of various photosensitizers on the photoreduction rate of methyl viologen. Curve a: Ru(dime-phen)$_3^{2+}$, Curve b: Ru(dime-phen)$_3^{2+}$ + Hm, Curve c: Ru(dime-phen)$_3^{2+}$ + Hm + Zn–TPP. Reaction mixture (6 cm^3) contains surfactant CDBAH (5.3 × 10^{-3} mol dm^{-3}), methyl viologen (7.8 × 10^{-5} mol dm^{-3}), mercaptoethanol (1.7 × 10^{-1} mol dm^{-3}) and photosensitizers, (irradiated by 150 W tungsten lamp at 30 °C).

In the case of the Ru(dime-phen)$_3^{2+}$ system as shown by curve a, the initial rate of methyl viologen reduction increased linearly at low concentration of Ru(dime-phen)$_3^{2+}$, and then the rate tends to reach a constant value at a high concentration of Ru(dime-phen)$_3^{2+}$. As most of the light energy with wavelength around 460 nm was absorbed by Ru(dime-phen)$_3^{2+}$ at the higher concentration, the rate did not increase any more when Ru(dime-phen)$_3^{2+}$ concentration increased. By adding another photosensitizer, hematoporphyrin (Hm), to the system with the high concentration of Ru(dime-phen)$_3^{2+}$, further increase of the initial rate was observed (curve b in the figure). Similar to the Ru(dime-phen)$_3^{2+}$ system, the methyl viologen reduction rate increased linearly at low concentration of Hm and reached a constant value. The increase of the activity may be caused by the photoreduction of methyl viologen with Hm excited by the light with different wavelength from Ru(dime-phen)$_3^{2+}$. By adding the third photosensitizer, Zn–TPP, a similar increase of the rate was observed as shown in the figure, curve c.

These results show that the efficiency of light harvesting could be increased by using a mixture of photosensitizers so as to cover the solar spectrum as well as possible in the scope of solar energy distribution on the earth surface.

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References

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