Preparation of an Azacrowned Isoluminol and Its Chemiluminescence Initiated by Alkali-metal Iodides in Acetonitrile

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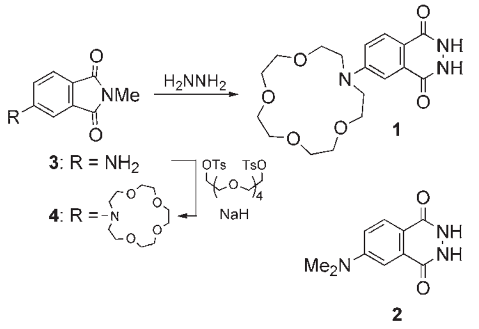
The novel azacrowned isoluminol has been prepared as the first luminol analogue possessing an azacrown ionophore. The crowned isoluminol displayed flash chemiluminescence upon addition of alkali-metal iodides in acetonitrile containing alkaline hydrogen peroxide and the chemiluminescence intensity varied depending on the metal cations studied; $K^+ \gg Na^+ > Li^+$.

According to the molecular design in which a chromophore is bound to a host function, numbers of chemosensors have been developed.[1] In spite of extensive studies on such chemosensors, only a few investigations have appeared on chemiluminescent materials possessing a guest-specific host.[2,3] Chemiluminophores having a receptor function would be of interest from the aspect of highly sensitive chemosensors.[4] We have reported that modification of a chemiluminophore with a host function is useful to modulate its chemiluminescence (CL) properties by addition of a specific guest.[2,3] The CL of luminols has been extensively studied,[5] however, very little information has been available on the CL of a luminol analogue possessing a crown-ionophore function. Herein, we describe preparation of a novel crowned isoluminol **1** and modification of its CL behavior by addition of alkali-metal iodides.

The crowned isoluminol **1** was prepared by the route shown in Scheme 1. Aminophthalimide **3** was treated with pentaethylene glycol ditosylate in the presence of NaH to give the crowned precursor **4** in 20% yield.[6] Subsequent reaction of the phthalimide **4** with hydrazine afforded the desired isoluminol **1** in an excellent yield (97%). The structure of the crowned isoluminol was confirmed by ^1H and ^{13}C NMR and HRMS spectra.[7] Additionally, the 6-aminophthalazine-1,4-dione chromophore of isoluminol **1** was established by electronic absorption spectra.[8]

The crowned isoluminol **1** displayed quite weak CL in acetonitrile in the presence of hydrogen peroxide and tetrabutylammonium hydroxide (Bu_4NOH). In contrast, addition of alkali-metal iodide to this mixture triggered off intense, blue CL. The CL was short-lived and ceased within a few seconds at room temperature (Figure 1). Alkali-metal perchlorates were also effective to cause the CL reaction. Addition of alkali-metal tetrafluoroborate was not effective in initiating the CL. In aqueous alkaline hydrogen peroxide solution, such CL was not detected by addition of alkali-metal iodides. As alkaline hydrogen peroxide in MeCN serves as a strong oxidant,[9] iodide ion can be oxidized under the present conditions. The present CL is, thus, considered to occur by contribution of oxidized species of iodide ion in acetonitrile.[10]



Scheme 1. Synthetic route to the crowned isoluminol **1**.

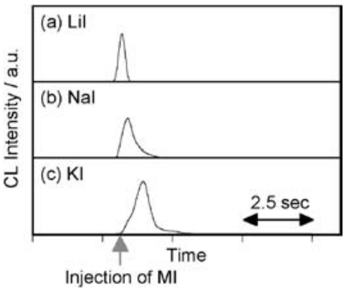


Figure 1. Time profiles of the CL of crowned isoluminol **1** (0.8 mM, MeCN) in the presence of H_2O_2 (excess) and Bu_4NOH (8 mM) observed at 450 nm and 25 °C upon addition of metal iodides (8 mM).

The CL spectra of isoluminol **1** observed upon addition of alkali-metal iodides (9–10 equiv.) are shown in Figure 2. The CL spectra were measured by a multi-channel photodiode array detector (Hamamatsu Photonics M2493 equipped with an image intensifier unit M2492). The CL emission appeared in the wavelength region of 350–620 nm and the maximum of the CL spec-

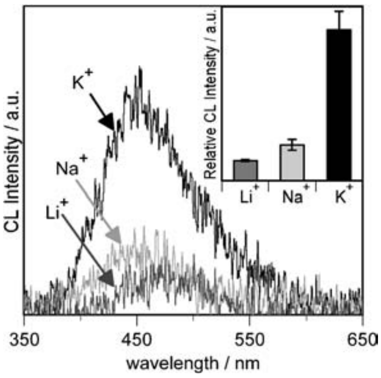


Figure 2. CL spectra of the isoluminol **1** (0.72 mM, MeCN) in the presence of H_2O_2 (excess) and Bu_4NOH (6.7 mM) detected upon addition of alkali-metal iodides (8 mM). The inset shows the relative intensity of the CL of **1**.

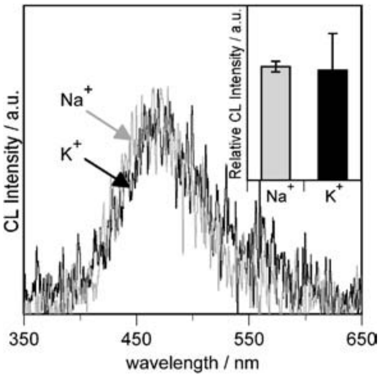


Figure 3. CL spectra of the isoluminol **2** (0.83 mM, MeCN) in the presence of H_2O_2 (excess) and Bu_4NOH (6.7 mM) detected upon addition of alkali-metal iodides (8 mM). The inset shows the relative intensity of the CL of **2**.

trum (λ_{CL}) was slightly affected by the alkali-metal cations (Li^+: 475, Na^+: 450, and K^+: 453 nm). On the other hand, the intensity of the CL changed significantly depending on the metal cations. As shown in the inset of Figure 2, the intensity of the CL increased in the order of $Li^+ < Na^+ \ll K^+$ (Relative intensity; Li^+:Na^+:K^+ = 1:1.8:7.5).[11] Therefore, it was indicated that the CL intensity of the isoluminol **1** could be modified by alkali-metal cations.

In the case of the control isoluminol **2**, which possesses no crown host function, CL was also observed under the same conditions as those used for the CL of crowned isoluminol **1**. However, the λ_{CL} and the CL intensity were not changed appreciably by the metal cations (Figure 3). Therefore, it is concluded that the azacrown host function of the isoluminol **1** plays an important role in the CL modification.

Fluorescence spectra of isoluminol **1** were measured in MeCN containing Bu_4NOH to obtain an insight into interactions between isoluminol **1** and metal cations. As shown in Figure 4, addition of K^+ displayed minimal effects on the fluorescence, while that of Li^+ or Na^+ caused appreciable blue-shift of the emission band and the spectral shift was more pronounced for Li^+. Thus, for the metal cation which displayed more significant interaction with isoluminol **1** (Li^+ and Na^+), the lower CL intensity was observed. It has been pointed out that, for luminol CL system, decrease of electron-donating ability of the substituent on the aromatic ring results in reduction of CL efficiency.[10] Thus, in the present case, association of the azacrown part with Li^+ or Na^+ may decrease electron-donating nature of the azacrown nitrogen atom resulting in the lower CL intensity (Figure 2).

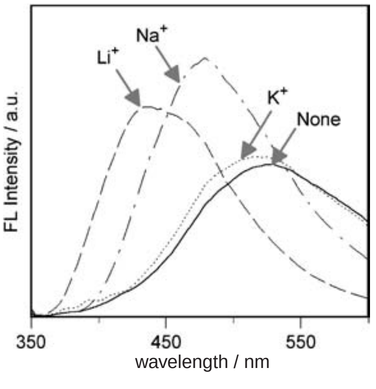


Figure 4. Fluorescence spectra (λ_{ex} 337 nm) of the crowned isolumonol **1** (5×10^{-5} M, MeCN) in the presence of Bu_4NOH (2.5×10^{-4} M) and alkali-metal iodides (2.5×10^{-4} M).

In order to discuss the mechanism by which the CL properties are modulated by metal cations, it is also important to reveal the light emitter in the CL reaction and its fluorescence properties. Unfortunately, the final product has not been isolated, thus, the light emitter was currently not specified.

In summary, the azacrown-modified isoluminol **1** has been prepared and its CL intensity could be modified by alkali-metal cations to show that the isoluminol **1** serves as a potential CL sensing probe for metal cations.

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7 Physical data for **1**: colorless crystals; mp 173–175 °C; ^1H NMR (500 MHz, $CDCl_3$) δ 3.62 (brs, 4H), 3.69 (brs, 8H), 3.71 (t, 4H, $J = 6.0$ Hz), 3.81 (t, 4H, $J = 6.0$ Hz), 7.13 (d, 1H, $J = 8.9$ Hz), 7.22 (brs, 1H), 8.05 (d, 1H, $J = 8.9$ Hz), 12.45 (brs, 1H), 13.45 (brs, 1H); IR ν_{max} (KBr) 1651, 1607 cm^{-1}; ^{13}C NMR (125 MHz, $CDCl_3$) δ 158.4, 157.2, 151.0, 128.4, 127.4, 117.2, 115.6, 104.3, 71.2, 70.2, 69.9, 67.9, 53.0; UV–vis (MeCN) λ_{max} 303 ($\log \varepsilon$ 4.21), 285 (4.32), 234 (4.16sh), 228 (4.20), 219 nm (4.17sh); HRMS (FAB) m/z: calcd for $C_{18}H_{26}N_3O_6$, 380.1822; found, 380.1787.
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11 The relative CL intensity was determined by integration of the spectra in the wavelength region 350–620 nm.

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