Novel Photoinduced Electron-transfer Sensor for Saccharides based on the Interaction of Boronic Acid and Amine

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Boronic acid derivative **1** displays a remarkable fluorescence enhancement over a large pH range in aqueous media upon the saccharide binding.

Photoinduced electron transfer (PET) has been wielded as a tool of choice in fluorescent sensor design for protons and metal ions.[1] Design of fluorescent sensors for neutral organic species presents a harsher challenge due to the lack of sufficient electronic changes involved upon inclusion. Complexation of neutral saccharides with boronic acid *via* covalent interactions in aqueous media has drawn our attention[2] due to its superiority to hydrogen bonding interactions found in other synthetic receptor systems in aqueous media.[3] However, the design of a fluorescent sensor based on the boronic acid saccharide interaction has been difficult due to the lack of sufficient electronic changes found in either the boronic acid moiety or in the saccharide moiety. Furthermore, facile boronic acid saccharide complexation occurs only at high pH, such conditions required to create a boronate anion. It has been shown that saccharide complexation does change the pK_a of the boronic acid moiety.[2–5] It has been observed that 2- and 9-anthrylboronic acids display enhanced acidity upon binding to saccharides and consequent fluorescent suppression by the boronate anion *via* a PET mechanism.[5] However, the PET from the boronate anion was not efficient despite the fact that the boronate anion is directly bound to the chromopore [I (in the presence of saccharide)/I_0 (in the absence of saccharide) = *ca.* 0.9].

In order to overcome the above mentioned disadvantages of boronic acid saccharide interactions, we have modified the boronic acid binding site to create a better electron centre around the boronic acid moiety. In the molecular sensor **1** the basic skeleton of a known PET sensor **2** has been preserved.[6] In addition, the amine can interact intramolecularly with the boronic acid as in **3** creating a five-membered ring. Synthesis of **1** was readily achieved according to Scheme 1 from readily available starting materials.[7] The fluorescence pH profile of **1**, in unbuffered aqueous media, as given in Fig. 1, gave one large step at low pH (pK_a = 2.9) and a possible small step at high pH. The pK_a of **2** is known to be 9.3 (fluorescence measurements in ethanolic aqueous media).[6] The large shift of the pK_a is due to the interaction found between the boronic acid moiety and the amine group. However, the boronic acid–amine interaction does not inhibit the PET quenching process in the complex **1b** (Scheme 2). Complete separation of the amine and the boronic acid moiety at very high pH, as in **1c**, quenched the anthracene fluorescence further. However, the fluorescence decrease is not sufficient for the calculation of the pK_a. Almost identical UV and fluorescence specta (Fig. 2) found over the whole pH range imply the absence of any aggregation and also the independence of the anthracene fluorescent moiety from the boronic acid binding site. The introduction of saccharides (D-glucose and D-fructose) remarkably changes the fluorescence of **1** over a large pH range (Fig. 1). Scheme 2 is suggestive of the most important species involved in the fluorescence changes. The enhanced interaction between boronic acid and amine, upon saccharide binding, inhibits the electron transfer process giving higher fluorescence (as **1d** in Scheme 2). This increased interaction would be expected since the saccharide binding to boronic acid increases its acidity[2–5] creating a more electron deficient boron atomic centre. The two saccharides studied gave more or less the same fluorescence enhancements. More flexible and less bulky ethylene glycol gave very low fluorescence enhancements suggesting the importance of some steric factors. The pK_a for the saccharide complex as calculated from fluorescence measurements at high pH (pK_a = 11.1) is in line with the second pK_a of **3** in the absence of sugar (pK_a = 11.8)[8] which is the parent binding site of **1**. However, no significant difference was found between fructose and glucose. From these fluorescent measurements we could not estimate the first pK_a of the saccharide-**1** complex owing to insufficient changes in fluorescence intensities.

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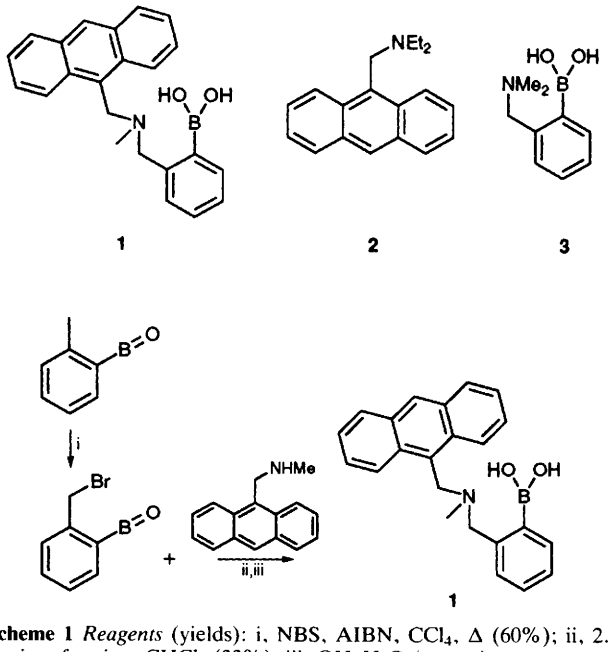


Scheme 1 *Reagents* (yields): i, NBS, AIBN, CCl_4, Δ (60%); ii, 2.1 equiv. of amine, $CHCl_3$ (33%); iii, OH–H_2O (quant.)

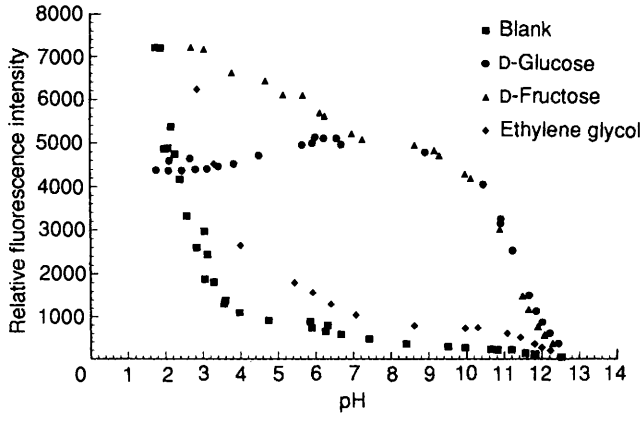
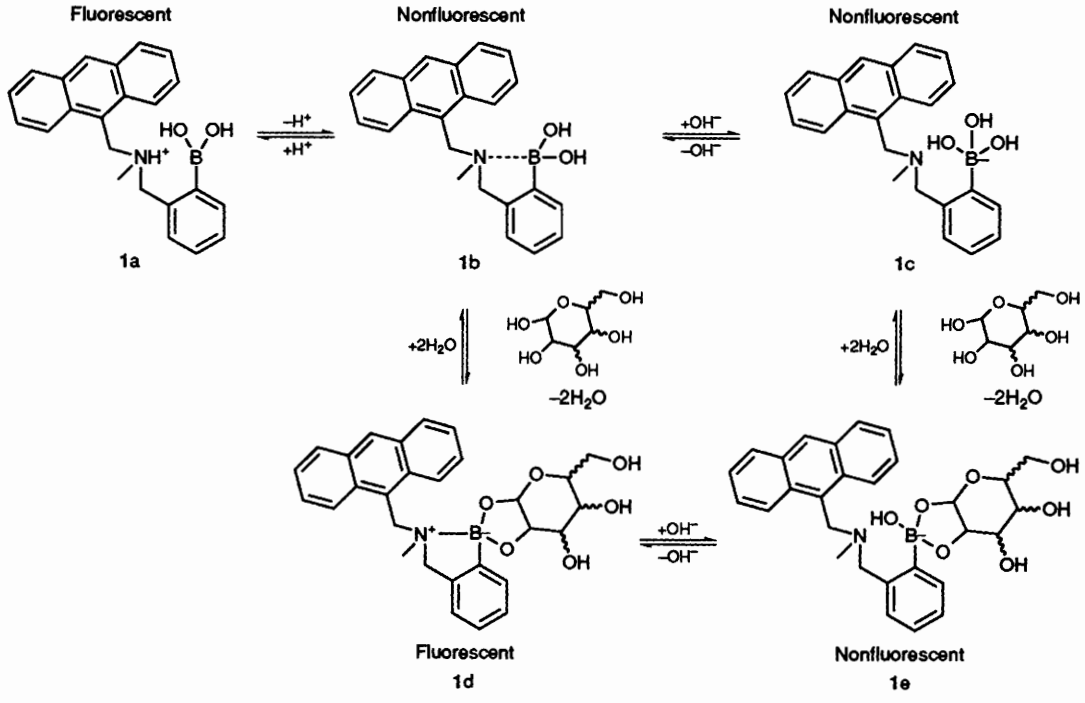


Fig. 1 Fluorescence intensity pH profile of **1** at 25 °C; 1.2 × 10^{-5} mol dm^{-3} of **1** in 0.05 mol dm^{-3} NaCl solution, [saccharide or ethylene glycol] = 0.05 mol dm^{-3}; λ_{ex} 370 nm, λ_{em} 420 nm



Scheme 2

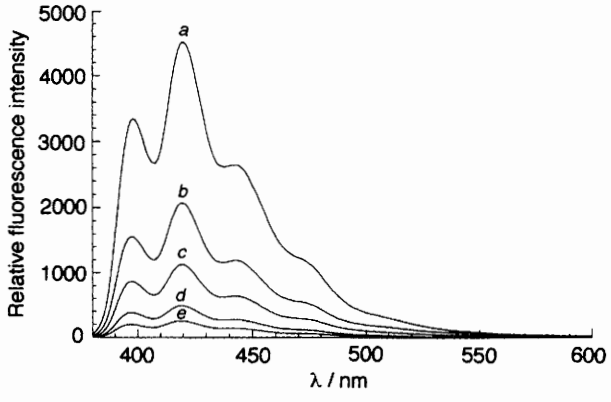


Fig. 2 Fluorescence spectra of **1**+ D-glucose complex in aqueous 0.05 mol dm^{-3} NaCl solution at 25 °C: (*a*) pH = 6.36; (*b*) pH = 10.27; (*c*) pH = 11.42; (*d*) pH = 11.98; (*e*) pH = 12.34; [D-glucose] = 0.05 mol dm^{-3}; [**1**] = 1.2×10^{-5} mol dm^{-3}; λ_{ex} 370 nm

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