"Reversible photochromism of an N-salicylidene aniline anion"

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ABSTRACT

The first N-salicylidene aniline anion showing reversible solid state thermochromic and photochromic properties is described. The photo-isomerization involves a trans-keto form which is stabilized thanks to the local anion surrounding. This photochromic anion can be used as a guest for the preparation of hybrid materials by insertion into a cationic host matrix. © 2014 The Royal Society of Chemistry.

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Reversible photochromism of an N-salicylidene aniline anion

An N-salicylidene aniline anion shows reversible photochromism at room temperature. This opens up the possibility to insert this guest charged molecule into various matrixes (polymers, molecular conductors, spin crossover switches and molecular magnets, coordination polymers and metal–organic frameworks...) in a controlled manner to prepare functional hybrids.
The first N-salicylidene aniline anion showing reversible solid state thermochromic and photochromic properties is described. The photo-isomerization involves a trans-keto form which is stabilized thanks to the local anion surrounding. This photochromic anion can be used as a guest for the preparation of hybrid materials by insertion into a cationic host matrix.

Photochromic molecules are of current interest, since they can find applications in optical data storage and displays. In particular, N-salicylidene aniline derivatives (anils) are considered as an important class for the preparation of hybrid materials since they can present both solid state thermo- and photochromism. Such materials were prepared by insertion of neutral anil derivatives inside host matrices such as clathrates, zeolites, mesoporous silicas, polymers, or cyclodextrins. While these methods do not allow precise control of the amount of guest anils, the use of molecular capsules, and the functionalization of these molecules as ligands, was reported. Unfortunately, the impact of coordination on the energy levels of anils is too important and the photochromic ability is lost after insertion. Anionic derivatives as counter-ions constitute an attractive alternative for the controlled incorporation into coordination complexes. To avoid Schiff base coordination competition, a sulfonate group was selected because of its permanent charge.

In this work, N-salicylidene p-aminobenzenesulfonate was crystallized, for the first time, in two steps using diallyl hexyl ammonium (Scheme 1). In contrast to previous observations with alkaline earth metals or alkaline metals, a photochromic salt with an important stabilization of the trans-keto form was obtained meaning that the photochromic ability of anilinesulfonate derivatives is mainly driven by structural properties. This discovery is a milestone in the use of N-salicylidene aniline sulfonate as a counter-ion in multifunctional materials, taking into account their high thermal stability.

The colours of N-salicylidene p-aminobenzenesulfonate diallyl hexyl ammonium (2) shown in Fig. 1 are meaningful. At 298 K, the yellow colour stems from the presence of the cis-keto form whereas the orange colour stems from traces of the trans-keto form (Fig. 1a). Upon cooling to 77 K, the cis-keto form converts to the white enol form, as shown by the light-orange colour (Fig. 1a).

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† Electronic supplementary information (ESI) available: Synthesis and crystal data of 2 and instrumentation. CCDC 947429 (2). For ESI and crystallographic data in CIF or other electronic format see DOI: 10.1039/c3cc45080e
The trans-keto form remains at 77 K since no intramolecular H transfer is possible between amine and keto groups (Scheme 2).

Solid state photochromism is observed by switching the colour from yellow-orange (cis-keto) to dark orange (trans-keto) after irradiation of 2 at λ = 450 nm for 30 min (Fig. 1b). This observation is confirmed by diffuse reflectance spectroscopy (Fig. 2).

The microcrystalline powder of 2 at 298 K shows three bands corresponding to the enol and keto forms of N-salicylidene p-aminobenzenesulfonate diallyl hexyl ammonium (Fig. 2). The band below 425 nm corresponds to the enol form whereas a contribution of the cis-keto form is observed between 425 and 550 nm. Above 550 nm, a third band appears after irradiation at λ = 450 nm for 20 min, which is attributed to the trans-keto form.²,³,¹⁵,¹⁶

Time-dependent experiments were performed in order to investigate the reversibility of the photochromism (Fig. 3). Thermal relaxation analysis shows interesting trans-keto stability after light irradiation (Fig. 3a). Indeed, a weak relaxation of the trans-keto form is noticed at 10 000 min (about 13% of trans-keto form are isomerized back into the cis-keto form).²⁰ This exceptional behaviour was earlier observed only for two examples.¹⁵,²¹

Diffuse reflectance spectra were also recorded with irradiation cycles at λ = 450 nm for 30 min to initiate the cis–trans isomerization and at λ = 546 nm for 30 min for the reverse photoreaction (Fig. 3b). These experiments highlight the photo-reversible cis–trans isomerization as well as the stability of the trans-keto form.

The crystal structure of 2 was measured at 150(2) K. 2 is solved in the monoclinic P2₁ space group. The asymmetric unit presents one N-salicylidene p-aminobenzenesulfonate anion and one diallyl hexyl ammonium cation (Fig. 4). The bond lengths C₁₈–O₁₉ (1.347(3) Å) and C₁₂–C₁₃ (1.444(3) Å) correspond to single bonds and N₁₁–C₁₂ (1.285(3) Å) is typical of a double bond (Table S1 in ESI†), which indicate that the major form observed in the crystal is the enol form. With its dihedral angle of 18(1)°, N-salicylidene p-aminobenzenesulfonate can be considered as nearly planar. The planarity of the molecule is also observed through the three torsion angles G₁, G₂ and G₃ (17(1)°, 179(1)° and −11(1)° respectively) (Table S1 in ESI†), which calls for thermochromic properties.²

The intramolecular hydrogen bond, observed between imine and enol functions (O₁₉–H₁₉ /C₁/C₁/C₁ N₁₁) with a bond length of 1.89(1) Å, allows the tautomeric equilibrium between enol and cis-keto forms. Two intermolecular hydrogen bonds at 1.98(1) and 2.51(1) Å (Table S2 in ESI†) and various closed contacts are observed in the crystal packing (Fig. 4). With respect to the average intermolecular distance (the distance between centroids of molecules of 4.6 Å), the packing can be however considered as ‘open’,² which allows the cis–trans isomerization upon light irradiation at 450 nm to proceed. Since the sulfonate anchors the anil switch to the diallylammonium, the rotation of the ketone bearing ring allows the photoisomerization with minimal
packing restraint (Scheme 3), compared to the usual photo-isomerization process in N-salicylidene derivatives. The presence of flexible neighbouring alkyl chains around the anil switch may favour this situation. On the other hand, the presence of intermolecular H-bonds in addition to van der Waals interactions may allow better stabilization of the trans-keto form (Table S2 in ESI†).

In conclusion, we have crystallized the first N-salicylidene anilinesulfonylate derivative, which shows solid state photochromism at room temperature, and thermochromism upon cooling. Taking advantage of its structural properties, the isomerization leads to the stabilization of the trans-keto form. This achievement is encouraging for the use of anionic N-salicylidene aniline derivatives in hybrid multifunctional materials, especially in FeII spin crossover compounds. Irradiating the anion should favour a photo-induced spin state change through a modification of the anion geometry, thanks to the AD-LISC effect. We anticipate that photochromic anions of this class shall be inserted into a wide range of functional cationic molecules (polymers, conductors, spin crossover switches and molecular magnets, coordination polymers and metal–organic frameworks, ...).

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Notes and references


19 F. Robert, Doctoral Thesis, Université Catholique de Louvain, 2010. This amount was evaluated thanks to the intensity difference in time dependent F(R) at t = 10 000 min.
