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Determination of deuterium oxide content in water based on luminescence quenching

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Abstract

Water molecules (H_2O) often reduce luminescence lifetimes of various luminescence probes. The change of lifetime is usually caused by dynamic luminescence quenching induced by O-H oscillators which effectively take away energy from excited molecule. The process can be described by Stern-Volmer equation. We have studied selected luminescence systems where it is possible to detect considerable changes of lifetime in presence/absence of H_2O and D_2O in this work for analytical purposes. We have tested both, inorganic (Ln^{3+}) and organic compounds using three different instrumentation in order to find the largest change between τ_H and τ_D. The Ln^{3+} containing systems have shown considerable increase/decrease of lifetimes in the presence/absence of D_2O (Eu^{3+}: τ_D/τ_H = 34.5) whereas organic systems gave significantly lower values of τ_D/τ_H (coumarin 123 lifetime ratio, τ_D/τ_H = 1.94). The calculated LOD varied from 0.04 mol.l^{-1} (samarium nitrate) to 6.55 mol.l^{-1} (riboflavin).

Keywords

Deuterium oxide determination; Time-Resolved Luminescence Spectroscopy; Luminescence quenching; Ln(III) luminescence; Organic compounds luminescence

Introduction

Deuterium oxide has plenty of applications in energetic industry, chemistry and physic. For example, it is used in pressurized heavy-water reactors (PHWR) as neutron moderator to slow down neutrons [1] and in neutrino detectors [2]. Thanks to different magnetic moment in comparison to normal water is used as a solvent in NMR spectroscopy [3]. Deuterium oxide is also used as the source of deuterium for isotopic labelling of organic compounds [4, 5], elucidation of biochemical reactions [6] and in various metabolic rate tests [7]. D_2O is also employed as a solvent instead of common water when collecting FTIR spectra of peptides and proteins [8]. H_2O creates a strong band that overlaps with the amide group region of peptides and proteins. The band from D_2O is shifted away from the amide region [9].

Determination of concentration of deuterium oxide in normal water by common analytical methods is laborious. The simplest methods are based on different physical properties of D_2O and H_2O. Freezing and boiling points of D_2O are 276.97 K, respectively 374.55 K. Density at SLP is 1.1056 (D_2O) and 0.9982 g.ml^{-1} (H_2O). For determination of heavy water can be employed also absorbance measurement using near IR spectroscopy (800–1300 nm region) but the method is less sensitive for higher concentration of D_2O [10]. Armani et al. has used ultra-high-Q optical microcavities for heavy water detection enabling determination of 1 part in 10^6 per volume [11]. Determination of concentration of deuterated water is possible also by mass spectrometry. Several works introduced GC-MS method for D_2O/H_2O determination [12, 13], whereas other authors suggested SIFT-MS analysis [14, 15]. Determination of deuterium oxide is possible also by means of NMR [16].