Synchronous-derivative phosphorimetric determination of 1- and 2-naphthol in irrigation water by employing \( \beta \)-cyclodextrin

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Abstract

A room-temperature phosphorimetric (RTP) study of the inclusion process between 1- and 2-naphthol, \( \beta \)-cyclodextrin (\( \beta \)-CD) and 3-bromo-1-propanol as heavy atom pertuber has been performed. Experimental conditions were optimized for the formation of trimolecular complexes with lifetimes of 10.82 and 9.41 ms for 1- and 2-naphthol, respectively. A synchronous-derivative room-temperature phosphorimetric method has been proposed to the analysis of both naphthols in synthetic mixtures and irrigation water in the ratio 1:10 to 10:1; the limit of detection is 0.02 mg ml\(^{-1}\) and the relative standard deviation (RSD) is about 6%. © 1999 Elsevier Science B.V. All rights reserved.

Keywords: Phosphorimetry; Cyclodextrins; 1-Naphthol and 2-naphthol; Synchronous-derivative technique; Irrigation water

1. Introduction

Since the first study about room temperature phosphorimetry (RTP) in fluid solution [1], several approaches have been used to produce emission phosphorescence from the metastable triplet state in this medium, such as sensitized-RTP [2] or by the use of micelles [3,4], cyclodextrins (CD) [5–7] or their mixtures [8], vesicles [9,10], microemulsions [11,12] and water-soluble copolymers [13]. CDs are the organized media which have been commonly used as hosts to originate inclusion complexes with a great variety of guest molecules; their analytical applications have been reviewed [14–16]. On the other hand, 1- and 2-naphthol have been determined in their mixtures by different techniques such as FIA with photometric detection [17], high-performance liquid chromatography (HPLC) [18], normal [19] and synchronous-derivative fluorimetry [20,21]. No references there are in the literature to the phosphorimetric quantitative analysis of mixtures of both naphthols, only qualitative data have
been found [22]. Synchronous technique has been proposed as a means of increasing the selectivity of phosphorimetry [23] due to its associated band-narrowing effect and together with derivative spectroscopy is a useful tool to discriminate mixtures of analytes with severe overlapped spectra. This approach, employed earlier in spectrofluorimetry [24,25] and in spectrophotometry [26] offers acceptable levels of precision and accuracy. In the present study the luminescence characteristics of the inclusion compounds of 1- and 2-naphthol in β-cyclodextrin (β-CD) aqueous solution have been investigated with the object of characterizing the inclusion process involved and proposing a phosphorimetric method for the determination of these compounds in their mixtures and in irrigation water. The proposed method shows good sensitivity and a higher selectivity due to the phosphorescence spectroscopy [7] coupled to synchronous-derivative technique together with the restrictive cavity of β-CD.

2. Experimental

2.1. Apparatus

All the fluorimetric and phosphorimetric measurements were carried out on a Perkin-Elmer (Norwalk, CT) LS-5 luminescence spectrophotometer equipped with a xenon discharge lamp (9.9 W) pulsed at line frequency (10 µs half-width, 50 Hz), Monk-Gillieson f/3 monochromators and 1 x 1 cm quartz cell which was capped with a teflon stopper. The spectrometer was connected to a Perkin-Elmer model 3600 data station provided with a PECLS II application software. Phosphorescence lifetimes were measured with an Obey-Decay application program on the mentioned software and the data were obtained automatically. When scanning phosphorescence spectra the delay time (\( t_d \)) and the gate time (\( t_g \)) were set at 1 and 11 ms and the excitation and the emission slits were set at 5 and 20 nm, respectively. The system responds to spectral derivatives and the structure calculates the first and second derivative of a spectrum. The cell holder and samples were controlled thermostatically by a thermostatic bath Frigiterm, Selecta (Barcelona, Spain) at 20 ± 0.5°C.

2.2. Reagents

1- and 2-Naphthol were purchased from Sigma (St Louis, MO) and Merck, (Darmstadt, Germany) respectively and used without further purification. 2000 µg ml⁻¹ stock solutions were prepared in 1-propanol and working solutions were obtained by dilution with this solvent. Anhydrous β-CD (Sigma) was used as received. Cyclodextrin solutions (0.01 M) were prepared in deionized water. A buffer solution (pH 4.8) was prepared from 1 M sodium acetate and acetic acid. Purified water (Milli Q/Milli-Q2 system, Millipore, Bedford, MA) was used. Unless otherwise stated, the reagents used were of analytical reagent grade.

2.3. Procedures

2.3.1. Study of inclusion phenomena

To aliquots of naphthols in acetone, gently evaporated, were added increasing volumes of \( 1 \times 10^{-2} \) M β-CD solution and deionized water up to a final volume of 10 ml. These samples were sonicated during 10 min and their fluorescence spectra were recorded.

2.3.2. Phosphorimetric determination of 1- and 2-naphthol

Aliquots containing 0.5–100 µg of 1- and 2-naphthol in 1-propanol were transferred into a 10 ml calibrated flask. Add 1-propanol up to a final volume of 50 µl, 1.5 ml of pH 4.8 acetic–acetate buffer solution, 100 µl of 3-bromo-1-propanol and dilute to the mark with 0.01 M aqueous β-CD. The samples were stirred by hand for 3 min, left for 20 min and the second derivative synchronous spectra were recorded between 280 and 380 nm against a reagent blank with the following instrumental parameters: \( \Delta \lambda = 180 \) nm, a scanning speed of 240 nm min⁻¹, a response time of 2 s and an integer factor of 20. The second derivative analytical values were measured as the vertical difference in the \( d^2 I_p \) scale from the corre-
sponding isodifferential point to the break with the second derivative curves (329.1 nm for 2-naphthol and 342.9 nm for 1-naphthol). The concentration of 1- and 2-naphthol in the binary mixtures is determined from the corresponding calibration graph previously run under similar conditions to those of the mixture.

2.3.3. Determination of 1- and 2-naphthol in irrigation water

To aliquots of samples, without filtration, 50 μl of 1-propanol, 1.5 ml of pH 4.8 buffer solution, 100 μl of 3-bromo-1-propanol and 94.7 mg of solid β-CD (final concentration 8.35 × 10⁻³ M) were transferred into a 10 ml calibrated flask. The samples were sonicated for 3 min, left for 20 min and their phosphorescence was measured as previously described.

3. Results and discussion

3.1. Spectral characteristics

Both naphthols form inclusion compounds with β-CD with stoichiometry 1:1 calculated by continuous variations method. The association constants of both naphthols were calculated from fluorescence data, by using the changes produced on the fluorescence spectra, for the expression described previously [27] and the values obtained were 644 ± 50 and 718 ± 40 M⁻¹ for 1- and 2-naphthol, respectively. The phosphorescence excitation and emission spectra of both species in a β-CD medium, at pH 4.8 are shown in Fig. 1. The excitation spectra show maxima at 255, 265 and 300 nm for 1-naphthol and 240, 255 and 330 nm for 2-naphthol. The emission spectra present

![Fig. 1. Excitation and emission spectra of 1- and 2-naphthol. [1-naphthol] = 1 μg ml⁻¹ and [2-naphthol] = 3 μg ml⁻¹, [β-cyclodextrin (CD)] = 8.3 × 10⁻³ M, pH 4.80, [3-Br-1-propanol] = 0.11 M, scanning speed 240 nm min⁻¹, response 2 s.](image)
3.2. Effect of varying reaction conditions

3.2.1. Effect of pH

Fig. 2 shows the dependence of phosphorescence of both naphtols with pH; the curves present maximum and constant intensity in the range 4–6 U of pH. Acetic–acetate buffer was used to adjust at pH 4.8.

3.2.2. Effect of solvent

To avoid the elimination of solvent by heating samples and then to have to sonicate, a study to choose an adequate solvent was done. Acetone, methanol, and ethanol totally quench the phosphorescence emission, this fact was not observed with 1-propanol. The influence of concentration of 1-propanol is shown in Fig. 3. From these kinetic curves it can be observed that the equilibrium is attained slower as the concentration of alcohol increases, with the values of the slope of the kinetic curve $0.128 \text{ s}^{-1}$ in the absence of alcohol and decreasing to $0.028 \text{ s}^{-1}$ for $2 \text{naphthol}$ (curve 7). The molecules compete between the apolar cavity of $\beta$-CD and its affinity or solubility in 1-propanol. Similar behaviour was observed for 2-naphthol. A compromise concentration between rapidity and facilities to prepare samples of both naphtols in 1-propanol was decided ($6.6 \times 10^{-2} \text{ M}$, i.e. $50 \mu l$ in a final volume of 10 ml).
3.2.3. Influence of heavy atom

Several aliphatic alkane halides, halogenated alcohols and mineral salts were investigated as heavy atoms perturbers. Generally, no RTP of the naphthols was observed from mineral salts (KBr,TlNO₃,…), but with some aliphatic alkane halides (1,2-dibromoethane, 1,3-dibromopropane…) and with some halogenated alcohols, RTP emission was obtained in turbid solutions, less in samples prepared with halogenated alcohols, due to the immiscibility of the heavy atom. Maximum emission was obtained by employing 3-bromo-1-propanol (Table 1). Its concentration affects the kinetic of the formation of the trimolecular complex β-CD-heavy atom-analyte and the intensity of the phosphorescence signal in the equilibrium. At lowest concentrations of heavy atom (< 5.5 × 10⁻² M) the coupling S–T is poor and the subsequent population of the triplet state is slow, and at highest concentrations (> 8.3 × 10⁻² M) the equilibrium is attained at 15 min for 1-naphthol and 20 min for 2-naphthol. This last time is fixed to obtain the measurements and 100 µl of 3-bromo-1-propanol in 10 ml of sample (11.1 × 10⁻² M) is added. The data show that phosphorescence emission is observed, generally, with heavy atoms non-ionics, aliphatic alkanes containing bromine (not chlorine) and the rest of the upper alkane to methyl group. The heavy atom may act as a wedge which gives more strength to the inclusion compound to adjust the molecule of naphthol to the cavity and to favour

Fig. 3. Dependence of the phosphorescence emission of 1- and 2-Naphthol aqueous solution of β-cyclodextrin (CD) (8.3 × 10⁻³ M) as a function of the concentration of 1-propanol; for 1-naphthol: (1) 0; (2) 0.013 M; (3) 0.066 M; (4) 0.13 M; (5) 0.26 M; (6) 0.52 M; for 2-naphthol: (7) 0.066 M; [naphthol] = 1 µg ml⁻¹, pH 4.80.
Table 1
Phosphorescence intensity ($I_p$) and lifetime ($\tau$) of 1- and 2-naphthol with different heavy atoms

<table>
<thead>
<tr>
<th>Heavy atom</th>
<th>1-Naphthol $\tau$ (ms)</th>
<th>2-Naphthol $\tau$ (ms)</th>
<th>$I_p$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,2-Dibromoethane</td>
<td>1.32</td>
<td>12</td>
<td>1.09</td>
</tr>
<tr>
<td>1,3-Dibromopropane</td>
<td>4.07</td>
<td>38</td>
<td>3.79</td>
</tr>
<tr>
<td>Dibromomethane</td>
<td>–</td>
<td>–</td>
<td>0.79</td>
</tr>
<tr>
<td>2-Bromoethanol</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>3-Bromo-1-propanol</td>
<td>10.81</td>
<td>85</td>
<td>9.41</td>
</tr>
<tr>
<td>1,3-Dichloro-2-propanol</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Bromoform</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Chloroform</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>AgNO$_3$</td>
<td>–</td>
<td>4.88</td>
<td>17</td>
</tr>
</tbody>
</table>

\(^a\) Other heavy atoms assayed were: Pb(NO$_3$)$_2$, Hg(NO$_3$)$_2$, Hgl$_2$, KBr, KI, TlNO$_3$, and 2-bromoethylammonium bromide. All of them were in 0.1 M concentration. [Naphthol] = 1 $\mu$g ml$^{-1}$.

the increase of the coupling S–T due to a great proximity of the heavy atom and originating a trimolecular complex (Fig. 4). The heavy atom can probably orient itself into the cavity with the –OH hydrophilic terminal directed to aqueous bulk and can interact by hydrogen bonding with the –OH group of naphthol fixing the molecule, while the hydrophobic terminal is directed into the cavity adjusting as a wedge and increasing its immobility and decreasing the vibronic effects. The –OH group in location 1 (1-naphthol) is more protected than the group in location 2 (2-naphthol) in relation to the aqueous environment. In this case this group can interact more easily with water molecules and for this reason its accommodation in the cavity is more slow and the coupling S–T is more disfavoured (phosphorescence emission is less intense). Table 1 presents the lifetimes ($\tau$) of naphthols obtained with different heavy atoms. The lifetimes were calculated by employing the Obey-Decay application program with delay times between 0.03 and 7 ms, doing ten measurements with correlation coefficients between 0.993 and 0.999 considering a monoexponential decay (with 3-bromo-1-propanol, $\tau$ for 1-naphthol is 10.82 ms implying a longer time in the excited state than 2-naphthol, $\tau$ is 9.41 ms). A delay time of 1 ms and a gate time of 11 ms were chosen for giving the best signal to noise ratio (SNR).

3.2.4. Influence of $\beta$-CD concentration, temperature and order of addition

The phosphorescence intensity increases as the $\beta$-CD concentration does (Fig. 5), and the time to attain the equilibrium is shorter in all the experiments if $\beta$-CD concentration was maintained at 8.85 $\times$ 10$^{-3}$ M. It is not necessary to eliminate the oxygen in the $\beta$-CD solution. The addition of sodium sulphite does not ameliorate the kinetic of the phosphorescence process. The equilibrium is attained at 5 min for 1-naphthol and 20 min for 2-naphthol; this time is chosen for this work. Sonication of the samples has no influence. Raising the temperature from 15 to 45° decreases the relative phosphorescence intensity of 1-naphthol from 100 to 5%. The work reported here was carried out at 20 $\pm$ 0.5°. Under these conditions, the phosphorescence intensity remains stable for at least 2 days. The order of the addition is important and the sequence sample, buffer, heavy atom and CD is recommended.

3.2.5. Selection of instrumental parameters

The phosphorescence spectra of both naphthols present broad bands whose overlapping does not allow the discrimination of the individual components in mixtures. However, the band narrowing effect and the associated spectral profile simplification provided by synchronous scanning phosphorimetry, together with the derivative approach, permit the quantitative and simultaneous determination of both naphthols in mix-
tures. Optimum $\Delta \lambda$ value ($\lambda_{em} - \lambda_{ex}$) was determined by recording various synchronous phosphorescence spectra at different values near the singlet–triplet splitting of two naphthols with the criterion of the largest, narrowest signal and maximal difference in the synchronous peaks. Fig. 6 shows the synchronous spectra of 1- and 2-naphthol registered at various $\Delta \lambda$, $v_{\text{scan}} = 240$ nm min$^{-1}$ and response time of 2 s. It can be observed that there is a difference of 26 nm between the wavelength maxima when $\Delta \lambda$ is increased from 130 to 190 nm, the difference being only 7 nm for 2-naphthol. As a compromise situation between maximum spectral intensity, half bandwidth at half maximum intensity and separation between wavelength maxima of both naphthols, a $\Delta \lambda$ of 180 nm have been chosen. At this $\Delta \lambda$ (the separation between maxima is 15 nm) the overlapped synchronous spectral bands impede the quantitative discrimination of both species. But the synchronous derivative approach adds a great power of discrimination. The main instrumental parameters affecting the shape of the derivative spectra are: the derivative order, wavelength scan speed and the response time. In the case of LS-5 spectrofluorimeter the number of data points has to be optimized; high numbers give better SNR in both first and second derivatives, thus 81 data points, corresponding to an integer factor of 20, were chosen for the experimental work. The synchronous-second derivative phosphorescence spectra of both naphthols are shown in the Fig. 7 which appear at isodifferential points at 329.1 and 342.9 nm. These points are of analytical interest because the contribution to the derivative amplitude from one component is zero in the isodiffer-

![Figure 5](image_url)

Fig. 5. Influence of the concentration of β-cyclodextrin (CD) on the phosphorescence emission of 1- and 2-naphthol; [naphthol] = 1 $\mu$g ml$^{-1}$, [3-Br-1-propanol] = 0.11 M.
ential scale; consequently, in a mixture, measurements from these points are independent of the concentration of this compound.

3.2.6. Quantitative analysis and main analytical figures of merit

It is assumed that Beer’s law is obeyed in the concentration range studied and that the derivative of a spectral band is the sum of the derivatives of its individual bands. The intensity of phosphorescence is given by the following expression:

\[ I_p = 2.3\Phi_p I_0 \alpha bc \]  

(1)

where \( I_p \) is the phosphorescence intensity, \( \Phi_p \) is the phosphorescence quantum yield, \( I_0 \) is incident source intensity, \( \alpha \) is molar absorptivity, \( b \) is path-length, and \( c \) is the concentration in mol l\(^{-1}\) (this expression is valid if the product \( \alpha bc \) is \(< 0.01)\). The calibration graphs, in normal phosphorimetry, were linear over the range 0.3–10 μg ml\(^{-1}\) for both naphthols and fitted by the least-squares treatment are expressed by:

\[ I_p = 207 \text{[1-naphthol]} \quad r = 0.999 \]
\[ I_p = 90.4 \text{[2-naphthol]} \quad r = 0.998 \]

where \( I_p \) is the phosphorescence intensity, \( r \) the correlation coefficient and the [Naphthol] is in μg ml\(^{-1}\). Other analytical parameters are given in Table 2.

The second derivative of (1) is:

\[ \frac{d^2 I_p}{d\lambda^2} = 2.3\Phi_p I_0 \alpha bc \frac{d^2 c}{d\lambda^2} \text{ or } k\Phi_c \frac{d^2 c}{d\lambda^2} \]

For one mixture of two components:
Fig. 7. Synchronous second-derivative phosphorescence spectra of 1-naphthol (1–5) and 2-naphthol (6–10). [Naphthol] = 1, 3, 5, 7 and 10 μg ml⁻¹; pH 4.80, Δλ = 180 nm; scanning speed 240 nm min⁻¹, response 2 s.

at $\lambda_{1\text{iso}}$

$$\frac{d^2I_p}{d\lambda_1^2} = k \Phi_1 c \frac{d^2e}{d\lambda_1^2} + k \Phi_2 c \frac{d^2e}{d\lambda_2^2}$$

at $\lambda_{2\text{iso}}$

$$\frac{d^2I_p}{d\lambda_2^2} = k \Phi_1 c \frac{d^2e}{d\lambda_1^2} + k \Phi_2 c \frac{d^2e}{d\lambda_2^2}$$

When $d^2e/d\lambda_1^2 = 0$ or a constant value, the contribution of component 1 to the over-all amplitude is zero, and for this reason component 2 may be measured free of interference by component 1. The same applies to component 2 when $d^2e/d\lambda_2^2 = 0$. Relationships between $d^2I_p/d\lambda^2$ and the concentration of naphthols obtained from these isodifferential points are:

$$d^2I_p/d\lambda^2 = -102.0 \text{ [2-naphthol]} + 34.2,$$

$$r = 0.999,$$

at $\lambda_{\text{iso}} = 329.1$ nm (at this $\lambda$, $I_p$ is 15)

<table>
<thead>
<tr>
<th>Method</th>
<th>Species</th>
<th>$\lambda_{ex}$ (nm)</th>
<th>$\lambda_{em}$ (nm)</th>
<th>$\lambda_{iso}$ (nm)</th>
<th>LDRa (μg ml⁻¹)</th>
<th>$C_L$ (k = 3) (μg ml⁻¹)</th>
<th>$C_Q$ (k = 10) (μg ml⁻¹)</th>
<th>R.S.D.b (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>1-Naphthol</td>
<td>300</td>
<td>520</td>
<td>–</td>
<td>0.10–7</td>
<td>0.03</td>
<td>0.10</td>
<td>3.7</td>
</tr>
<tr>
<td>Normal</td>
<td>2-Naphthol</td>
<td>334</td>
<td>518</td>
<td>–</td>
<td>0.17–10</td>
<td>0.05</td>
<td>0.17</td>
<td>5.3</td>
</tr>
<tr>
<td>2nd derivat.</td>
<td>1-Naphthol</td>
<td>–</td>
<td>–</td>
<td>342.9</td>
<td>0.07–7</td>
<td>0.02</td>
<td>0.07</td>
<td>6.5</td>
</tr>
<tr>
<td>2nd derivat.</td>
<td>2-Naphthol</td>
<td>–</td>
<td>–</td>
<td>329.1</td>
<td>0.07–10</td>
<td>0.02</td>
<td>0.07</td>
<td>5.7</td>
</tr>
</tbody>
</table>

a Linear dynamic range.
b Relative standard deviation (R.S.D.), at 1 μg ml⁻¹ level.
Table 3
Phosphorimetric analysis of 1- and 2-naphthol in synthetic binary mixtures and irrigation water

<table>
<thead>
<tr>
<th>Ratio I/II (w/w)</th>
<th>Amount (I) (µg ml⁻¹)</th>
<th>Error (%)</th>
<th>Amount (II) (µg ml⁻¹)</th>
<th>Error (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Taken</td>
<td>Found*</td>
<td>Taken</td>
<td>Found*</td>
</tr>
<tr>
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<td>5.0</td>
<td>5.20</td>
<td>4.0</td>
<td>4.99</td>
</tr>
<tr>
<td>1:1</td>
<td>1.0</td>
<td>1.10</td>
<td>10.0</td>
<td>1.05</td>
</tr>
<tr>
<td>1:5</td>
<td>1.0</td>
<td>1.12</td>
<td>12.0</td>
<td>5.10</td>
</tr>
<tr>
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<td>0.1</td>
<td>0.11</td>
<td>10.0</td>
<td>0.48</td>
</tr>
<tr>
<td>1:7</td>
<td>1.0</td>
<td>1.10</td>
<td>10.0</td>
<td>6.77</td>
</tr>
<tr>
<td>1:10</td>
<td>0.1</td>
<td>0.11</td>
<td>10.0</td>
<td>1.04</td>
</tr>
<tr>
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<td>1.0</td>
<td>1.08</td>
<td>8.0</td>
<td>9.30</td>
</tr>
<tr>
<td>3:5</td>
<td>3.0</td>
<td>2.95</td>
<td>-1.7</td>
<td>5.00</td>
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<td>3.0</td>
<td>2.92</td>
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<td>6.77</td>
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<tr>
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<td>0.49</td>
<td>-2.6</td>
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<tr>
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<td>1.07</td>
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<td>1.0</td>
<td>1.10</td>
<td>10.0</td>
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<tr>
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<td>1.05</td>
<td>5.0</td>
<td>1.08</td>
</tr>
<tr>
<td>Sample 2</td>
<td>5.0</td>
<td>5.12</td>
<td>2.4</td>
<td>5.25</td>
</tr>
<tr>
<td>Sample 3</td>
<td>0.5</td>
<td>0.52</td>
<td>4.0</td>
<td>4.80</td>
</tr>
<tr>
<td>Sample 4</td>
<td>5.0</td>
<td>4.91</td>
<td>-1.8</td>
<td>0.55</td>
</tr>
<tr>
<td>Sample 5</td>
<td>1.0</td>
<td>1.07</td>
<td>7.0</td>
<td>9.20</td>
</tr>
</tbody>
</table>

* Mean of three separate determinations.

\[ \frac{d^2 I_p}{d \lambda^2} = 58.2 \text{ [1-naphthol]} + 8, \quad r = 0.999, \]

at \( \lambda_{iso} = 342.9 \text{ nm} \) (at this \( \lambda \), \( I_p \) is 4),

(Where the concentration of naphthols is expressed in µg ml⁻¹).

From the results obtained in the determination of synthetic binary mixtures of both naphthols (Table 3), it can be deduced that the reported method gives good results even at high ratios with acceptable levels of precision and accuracy.

4. Applications

The synchronous-derivative phosphorimetric procedure was applied to the determination of 1- and 2-naphthol in irrigation water samples taken in the Axarquia (area of east Malaga province) spiked with both naphthols. Table 3 summarizes the results; it can be concluded that acceptable accuracy and precision was obtained in the analysis of 1- and 2-naphthol in irrigation water.

5. Conclusions

It has been shown that 1- and 2-naphthol form inclusion compounds in β-CD aqueous solution with formation constants of 644 ± 50 and 718 ± 40 M⁻¹, respectively. By employing 3-bromo-1-propanol, as heavy atom perturber, an intense phosphorescence emission in β-CD aqueous solution is observed, with a maximum at 520 and 518 nm for 1- and 2-naphthol, being a strong overlapping of emission bands. Lifetimes were calculated from decay curves (10.82 and 9.41 ms, respectively). The variables affecting the formation of both complexes of inclusion have been studied. The kinetic of inclusion process for 2-naphthol is slower than 1-naphthol due to the different position of the group –OH in the molecule which is more protected in 1-naphthol. Mixtures of both species in the ratio 1:10 to 10:1 were simultaneously determined in irrigation water from a single scan by employing the synchronous-derivative technique with a relative standard deviation (R.S.D.) between 5 and 10% and limits of detection of 0.02–0.05 µg ml⁻¹.

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