Available online at www.sciencedirect.com

SCIENCE DIRECT®

Journal of Photochemistry and Photobiology A: Chemistry 162 (2004) 457–462

Journal of Photochemistry and Photobiology A:Chemistry

www.elsevier.com/locate/jphotochem

Flow injection chemiluminescence analysis for highly sensitive determination of noscapine

Yafeng Zhuang [a], Xilan Cai [a,b], Junsheng Yu [a], Huangxian Ju [a,*]

[a] Department of Chemistry, Institute of Analytical Science, State Key Laboratory of Coordination Chemistry, Nanjing University, Nanjing 210093, PR China

[b] Department of Technology, Jiangsu Police Officer College, Nanjing 210012, China

Received 16 July 2003; received in revised form 4 September 2003; accepted 20 September 2003

Abstract

Noscapine is an antitussive drug and possesses potent antitumor activity. This work establishes a highly sensitive method for its determination by flow injection chemiluminescence (CL) technique. This method is based on its strong sensitizing effect on the weak CL reaction between sulfite and acidic permanganate. The mechanism for the sensitizing process is proposed on the basis of fluorescence and CL spectra. Under optimal experimental conditions, the CL response is proportional to the concentration of noscapine over the range of 2.0×10^{-8} to 2.0×10^{-6} mol/l with a correlation coefficient of 0.9998 and a detection limit of 8.0×10^{-9} mol/l (3σ). The relative standard deviation for 11 repetitive determinations of 5.0×10^{-7} mol/l noscapine is 1.2%. Most of metal ions and some alkaloids such as morphine, codeine and heroin do not interfere with the determination. The interference of coexisted papaverine in the opium can be eliminated by the dilution of sample solution. The method has been satisfactorily used for the determination of noscapine in synthesized samples.

Keywords: Chemiluminescence; Flow injection analysis; Noscapine; Permanganate; Sulfite

1. Introduction

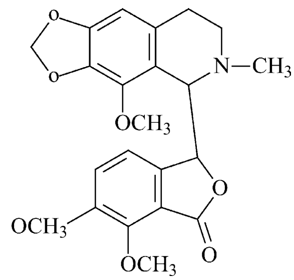
Noscapine (narcotine, as shown in Scheme 1) is the second most abundant alkaloid in opium, present in concentrations of 2–8% [1] and is usually used as an antitussive drug. Unlike morphine and codeine, noscapine has no analgesic activity or abuse potential. Its major pharmaceutical action is its antitussive activity, which has been reported to be equivalent to that of codeine [2]. Recent studies indicate noscapine can cause apoptosis in many cell types and has potent antitumor activity against solid murine lymphoid tumors and human breast and bladder tumors implanted in nude mice [3,4]. These works suggest that the antitumor activity of noscapine might lie in its initiation of apoptotic pathways. Compared with other microtubule drugs, noscapine has low toxicity and wide efficacy in animal models [5]. Thus, the quantitative determination of noscapine can provide important information on its biological function.

The British Pharmacopoeia (BP) procedures [6,7] for the quantitative determination of noscapine in pharmaceutical preparations include an absorption method, which lacks specificity, and an acid–base titrimetric method in a non-aqueous medium with potentiometric end-point detection. Neither method is suitable for the determination of low levels of the alkaloid [8]. Other previously published analytical assays include high-performance liquid chromatography (HPLC) [9–13], gas chromatography [14] and spectrophotometry [8]. The spectrophotometric method developed by Suliman et al can determine noscapine down to 3.64 μmol/l (1.5 ppm) [8]. A linear range from 1.74×10^{-8} to 6.53×10^{-7} mol/l for noscapine determination has been obtained using solid-phase extraction and HPLC [11]. For the practical application, it is necessary to develop a more simple and sensitive method for noscapine determination.

Chemiluminescence (CL) is becoming a powerful analytical tool due to its high sensitivity, wide dynamic range and simple instrumentation [15]. It has been exploited with a wide range of applications in different fields, such as biotechnology, pharmacology, molecular biology, and environmental chemistry [16,17]. A variety of organic and inorganic compounds, such as bile acids [18], riboflavin [19], morphine [20–22] and ascorbic acid [23], have been determined by using $KMnO_4$ as a reagent to generate CL. Recently, a wide range of analytical applications of

* Corresponding author. Tel.: +86-25-3593593; fax: +86-25-3593593.
E-mail address: hxju@nju.edu.cn (H. Ju).

1010-6030/$ – see front matter © 2004 Elsevier B.V. All rights reserved.
doi:10.1016/S1010-6030(03)00391-5



Scheme 1. Structure of noscapine.

$KMnO_4$ in CL reactions has been reviewed [24]. The nature of those reactions has been postulated to involve the following excited state species: manganese(II) or a complex thereof [20,25–27], singlet oxygen [28,29], sulfur dioxide [18,30,31], molecular nitrogen [32,33], and fluorescent oxidation products of the analyte [34]. Although the excited state species of manganese(II) or a complex thereof in the presence of hexametaphosphate has been well characterized by Barnett et al [27] in acidic potassium permanganate system, the CL spectrum of $KMnO_4$–Na_2SO_3–H_2SO_4 system shows the emission of the exited sulfur dioxide between 450 and 600 nm as reported in [30]. This work studies the effect of noscapine on the CL intensity emitted from the reaction of sulfite with acidic $KMnO_4$. A sensitizing effect of the noscapine on the CL emission is observed. Based on the sensitizing effect, a simple, rapid and sensitive flow injection CL method for noscapine detection is proposed. To our best knowledge, this is the first CL application to the determination of noscapine. It possesses a good accuracy and precision and has been used to determine noscapine in synthesized samples. In view of the facts that other alkaloids such as morphine, codeine and heroin do not interfere in the determination of noscapine and that the sensitizing effect of papaverine in a low level is unobservable, this method would be of superior selectivity for the noscapine detection. It has been reported that some illicit heroin samples contain a high content of noscapine (up to 61%) [35], therefore, this method could also be used for determination noscapine assay in these samples.

2. Experimental

2.1. Reagents

All reagents were of analytical grade. All solutions were prepared with deionized water of 18 MΩ purified from a Milli-Q purification system. Noscapine was obtained from the State Narcotic Laboratory, Beijing. $KMnO_4$ (Jintan, China) was used as received. The working solution of 3.0×10^{-5} mol/l $KMnO_4$ was prepared daily by diluting the stock solution of 0.01 mol/l $KMnO_4$ with 0.1 mol/l sulfuric acid. The solution of 0.01 mol/l sodium sulfite was prepared daily.

2.2. Apparatus

The FIA (flow injection analysis)-CL system is the same as that reported in [36]. Two pumps of Luminescence Analyzer (IFFM-D, Remex Electronic Instrument Limited Co., Xi'an, China) were used to deliver flow streams. Polytetrafluoroethylene (PTFE) tubing (0.8 mm i.d.) was used to connect all components in the flow system. The flow cell was a 10 cm length of spiral glass tubing (2.0 mm i.d.) and the distance between injection valve and flow cell was about 10 cm.

Fluorescence spectra were recorded by a RF-5301 spectrofluorimeter (Shimadzu, Japan). The CL spectrum was obtained with a series interference filters by the static method. The filters were inserted between the sample cuvette and the photomultiplier tube (PMT).

2.3. Procedures

Noscapine and acidic $KMnO_4$ solutions were mixed via a Y-shaped element and injected into the carrier stream (water) through a six-way injection valve. Sulfite solution was mixed with carrier stream via another Y-shaped element in front of the flow cell. The CL signal was detected by the photomultiplier tube (PMT) (CR-105, Hamamatsu Japan) placed near the flow cell and was recorded with a computer equipped with an A/D card. The wavelength of its max sensitivity of the PMT was 420 nm. The spectrum response range of the PMT was from 300 to 650 nm.

3. Results and discussion

3.1. Optimization of experimental variables

The typical CL signal of acidic $KMnO_4$ upon addition of 4.0×10^{-4} mol/l Na_2SO_3 was shown in Fig. 1. The reaction

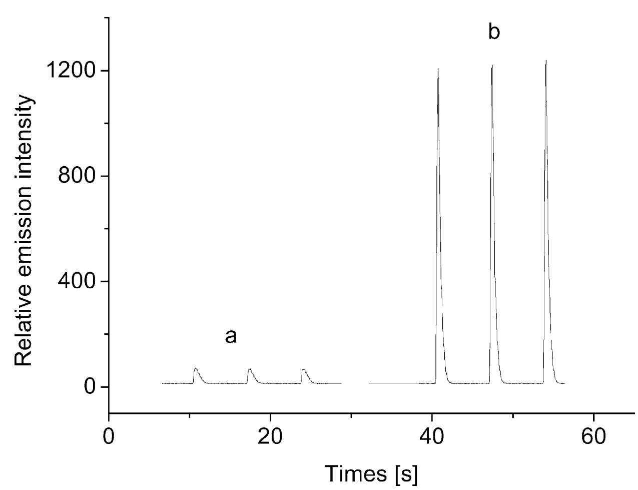


Fig. 1. Typical CL signals of 3.0×10^{-5} mol/l $KMnO_4$ + 0.1 mol/l H_2SO_4 upon addition of 4.0×10^{-4} mol/l Na_2SO_3 in the absence (a) and presence (b) of 5.0×10^{-7} mol/l noscapine.

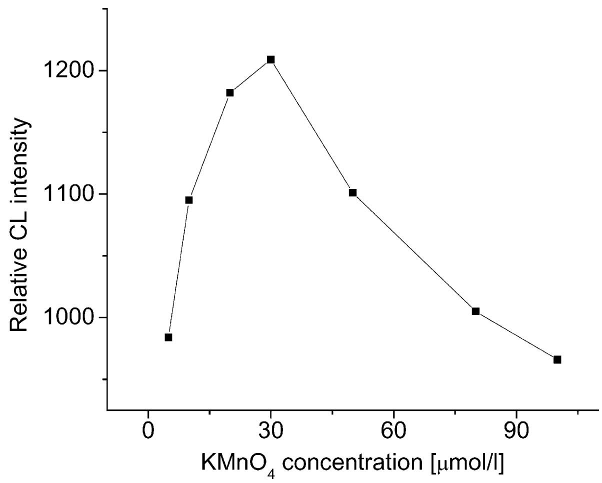


Fig. 2. Effect of $KMnO_4$ concentration on CL intensity of 0.1 mol/l $H_2SO_4 + 5.0 \times 10^{-7}$ mol/l noscapine $+ 4.0 \times 10^{-4}$ mol/l Na_2SO_3.

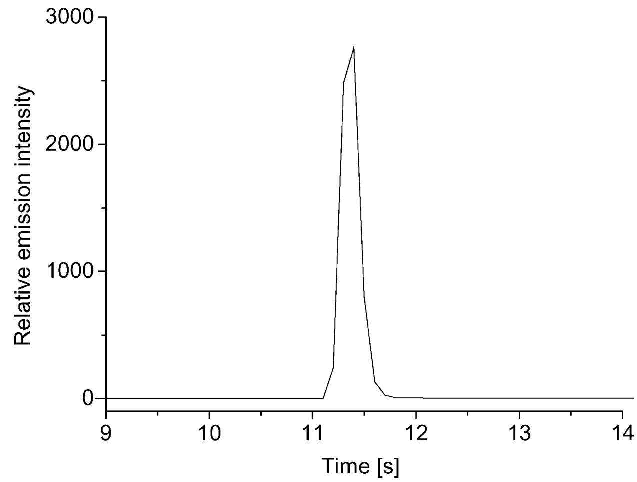


Fig. 3. Emission intensity vs. time profile after mixing of sulfite with acid potassium permanganate in the presence of noscapine.

between $KMnO_4$ and Na_2SO_3 produced a weak CL emission. When 5.0×10^{-7} mol/l noscapine was added in this system, the CL emission increased by 16.9 times. The significant increase indicated noscapine was a sensitive enhancer on the CL reaction of permanganate-sulfite. Furthermore, the emission intensity increased with an increasing concentration of noscapine. The sensitizing effect of noscapine on the weak CL emission was also related to the pH value of solution and the concentrations of $KMnO_4$ and sulfite. Thus, a series of experiments were performed to optimize the conditions for the production of maximum CL emission.

The effect of acid contained in the solution on the CL emission was initially examined. The CL emission intensity of noscapine-$KMnO_4$–Na_2SO_3 system in the presence of HCl, HNO_3, CH_3COOH, $H_6P_4O_{13}$, H_3PO_4 or H_2SO_4 at the same concentration was detected. The results indicated that the strongest CL emission occurred in acidic medium containing H_2SO_4. With the increasing concentration of H_2SO_4, the CL emission intensity increased and reached a maximum value at 0.1 mol/l. The intensity unchanged at higher H_2SO_4 concentrations. Therefore, 0.1 mol/l H_2SO_4 was chosen as the acidic medium for the reduction of permanganate.

Fig. 2 shows the effect of $KMnO_4$ concentration on the CL intensity. With an increasing concentration of $KMnO_4$, the CL intensity increased and then reached a maximum value at the $KMnO_4$ concentration of 3.0×10^{-5} mol/l. At the $KMnO_4$ concentrations higher than 3.0×10^{-5} mol/l, the emission intensity decreased probably owing to the permanganate absorbing the emitted light [26,37]. Therefore, 3.0×10^{-5} mol/l $KMnO_4$ was used for subsequent work.

The dependence of the CL intensity on the concentration of Na_2SO_3 showed a strongest emission at the concentration of 4.0×10^{-4} mol/l, which was chosen for the present work.

In flow injection analysis, the flow rate of each reagent stream is generally an important parameter. The flow rates of Na_2SO_3 solution and the carrier were set at the same value and were twice those of both $KMnO_4$ and sample solutions. The signal intensity increased with the increasing flow rate, as it was expected from the increased mixing rate. However, high flow rate led to much consumption of reagents and sample solutions but little gain in CL intensity and unstable CL signal. It was decided to supply the $KMnO_4$ and Na_2SO_3 solution at 0.9 and 1.8 ml/min, respectively.

3.2. Kinetic characteristics of the CL reaction

The kinetic behavior of the CL reaction of noscapine-$MnO_4{}^-$–$SO_3{}^{2-}$ was studied with a static method. Fig. 3 shows the typical kinetic curve. The CL reaction occurred immediately after mixing Na_2SO_3 with the solution containing $KMnO_4$ and noscapine and reached a maximum within 0.30 s. The CL reaction could be completed within 0.80 s after the reaction started. Thus, the CL reaction is very rapid. It is a flash-type emission and is apparently controlled by the mixing speed.

3.3. Analytical characteristics of noscapine

Under the optimum conditions mentioned above, the calibration curve was obtained for noscapine determination by plotting the CL signal versus noscapine concentration (Fig. 4), which gave a linear range from 2.0×10^{-8} to 2.0×10^{-6} mol/l with a correlation coefficient of 0.9998. The detection limit was 8.0×10^{-9} mol/l, which was calculated as the amount of noscapine required to yield a net peak three times the standard deviation of the background signal (3σ). The relative standard deviation for 11 repetitive determinations of 5.0×10^{-7} mol/l noscapine was 1.2%, showing a good reproducibility.

3.4. Interferences

The influences of different metal ions and organic compounds on the CL intensity were investigated by determining

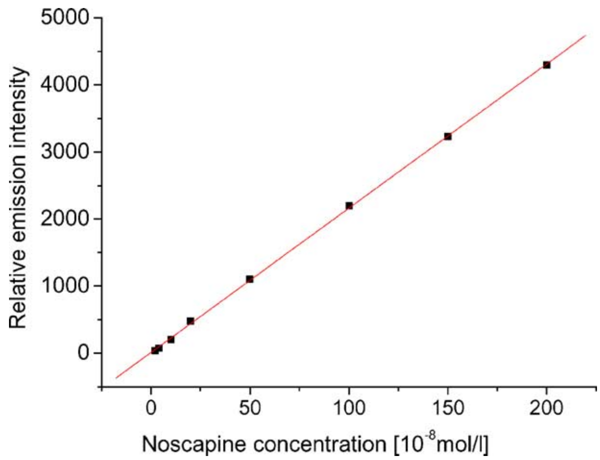


Fig. 4. Plot of CL emission intensity vs. noscapine concentration.

the CL emission of the solutions containing 5.0×10^{-7} mol/l noscapine and foreign species with continuously increasing concentration up to 5×10^{-5} mol/l. When the effect of each foreign species on the peak height was less than 5.0%, it was thought not to interfere the determination of noscapine. The results obtained were summarized in Table 1. Most anions had no interference because the tolerable ratios were in the case much higher than those normally encountered in real samples. No interference could be found when 100-fold concentration of morphine, codeine or heroin and 10-fold concentration of glucose, fructose or sucrose coexisted in the solution. Thus, this method could be used for the determination of noscapine in pharmaceutical preparations or biological fluids.

Papaverine at the concentration 1.6 times noscapine displayed an interference with the determination of 5.0×10^{-7} mol/l noscapine. Generally, the contents of noscapine and papaverine in opium are 2–8% [1] and 0.5–1% [38], respectively. Our previous work [36] reported a detection limit of 1.0×10^{-7} mol/l for papaverine determination using permanganate-sulfite system under the optimal conditions. Considering the much better sensitivity of this proposed method and higher content of noscapine than papaverine in opium, the interference of coexisted papaverine with the determination of noscapine in the opium sample could be eliminated by the dilution of sample solution.

Table 1
Tolerance to different substances in the determination of 5.0×10^{-7} mol/l noscapine

Species added	Maximum tolerable mole ratio[a]
Pb^{2+}, Zn^{2+}, Cd^{2+}, Ni^{2+}, La^{2+}, Cr^{3+}, Ca^{2+}	100
Mn^{2+}, Sn^{4+}, Sn^{2+}, Co^{2+}	50
Morphine, codeine, heroin	100
Glucose, fructose, sucrose	10
Papaverine	1.6

[a] 100 is the greatest ratio tested.

Table 2
Analytical results of noscapine in synthetic samples

Synthetic sample	Added (10^{-7} mol/l)	Found (10^{-7} mol/l)[a]	R.S.D. ($n = 4$) (%)	Recovery (%)[a]
Sample 1	1.00	1.03	1.7	103.0
	2.00	1.92	2.8	99.1
	3.00	3.05	0.5	101.6
	4.00	3.89	1.5	97.3
	5.00	4.93	1.7	98.6
Sample 2	1.00	0.99	3.5	99.0
	2.50	2.42	1.6	97.2
	3.00	3.13	5.4	104.3
	4.00	4.16	2.6	104.1

[a] Average of four determinations.

3.5. Determination of noscapine in synthesized samples

In order to verify the practical application of the proposed method, two simulated samples were prepared with appropriate amounts of some foreign species. Sample 1 contained 1.0×10^{-6} mol/l morphine, 2.0×10^{-4} mol/l glucose and 1.0×10^{-5} mol/l heroin, while sample 2 contained 1.0×10^{-5} mol/l Zn^{2+} and Ni^{2+}, 1.0×10^{-6} mol/l Co^{2+}, 1.0×10^{-7} mol/l morphine and 1×10^{-5} mol/l heroin. The results for the determination of noscapine were given in Table 2. The relative standard deviations less than 5.4% with an average value of 2.4% and the recoveries between 97.2 and 104.3% with an average recovery of 100.5% were highly satisfactory and illustrated the good performance of the proposed method.

3.6. CL mechanism

In order to investigate the possible sensitizing mechanism of noscapine on the weak CL reaction of $KMnO_4$–H_2SO_4–Na_2SO_3, the fluorescence spectra of noscapine, noscapine–H_2SO_4, noscapine–$KMnO_4$–H_2SO_4, and noscapine–$KMnO_4$–H_2SO_4–Na_2SO_3 were recorded, respectively. The fluorescence excitation and emission spectra of noscapine were shown in Fig. 5. The excitation spectrum detected at an emission wavelength of 402 nm showed a native fluorescence excitation wavelength of 305 nm (Fig. 5a). Its maximum emission wavelength detected at the excitation wavelength of 305 nm was 402 nm (Fig. 5b). Upon addition of 0.1 mol/l H_2SO_4 the fluorescent intensity of noscapine decreased greatly and the position of the maximum emission intensity shifted to 438 nm, which was detected at the excitation wavelength of 305 nm (Fig. 5c). Thus, the fluorescence spectrum was related to the solution pH value. In presence of 0.1 mol/l H_2SO_4, the addition of $KMnO_4$ resulted an increase in the fluorescent intensity detected at the excitation wavelength of 305 nm. The maximum emission wavelength remained at the same position (Fig. 6). Furthermore, with an increasing reaction time the fluorescent intensity increased and then tended to a maximum value. Thus, the fluorescence emission resulted from the oxidized

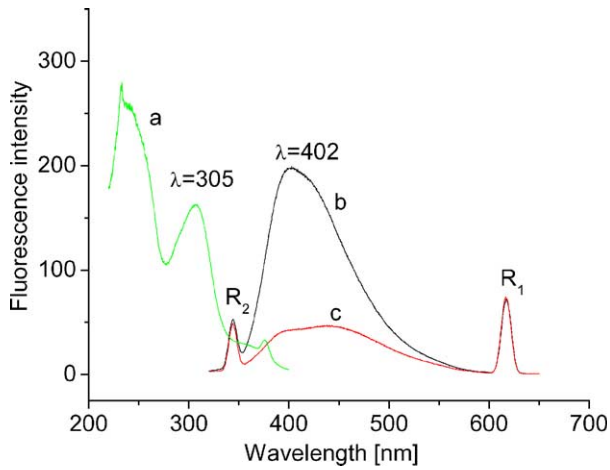


Fig. 5. Fluorescence excitation (a, dotted line) and emission (b, full line) spectra of 5.0×10^{-6} mol/l noscapine and fluorescence spectrum of 5.0×10^{-6} mol/l noscapine + 0.1 mol/l H_2SO_4 (c). R_1, Rayleigh scattering. R_2, Raman scattering of water.

form of noscapine and it possesses stronger fluorescence emission intensity.

The addition of Na_2SO_3 to noscapine–H_2SO_4 system did not change the fluorescent intensity of noscapine, however, the fluorescent intensity of the oxidized form of noscapine increased greatly upon addition of Na_2SO_3 to noscapine–$KMnO_4$–H_2SO_4 system. The emission wavelength also remained at the same position. On the contrast, no change was observed when Na_2CO_3 was added to noscapine–$KMnO_4$–H_2SO_4 system. Thus, a reaction occurred between the oxidized form of noscapine and HSO_3^- to form a strong fluorescent compound, which resulted in the increase in fluorescent intensity.

The CL spectrum of $KMnO_4$–Na_2SO_3–H_2SO_4 system showed one emission profile extending from 490 to 620 nm

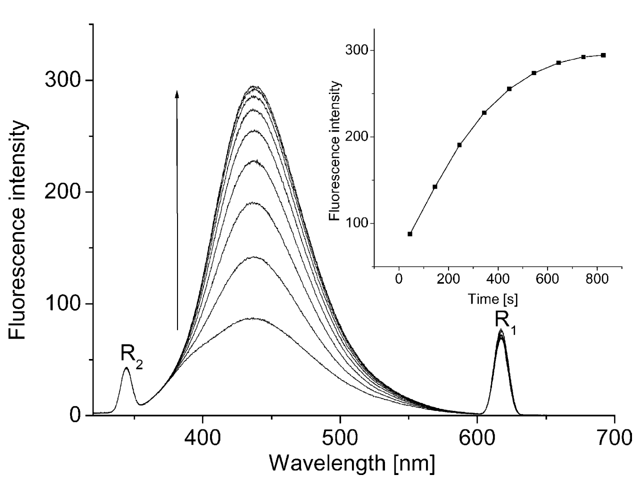


Fig. 6. Effect of the reaction time on the fluorescent intensity of 5.0×10^{-6} mol/l noscapine + 3.0×10^{-5} mol/l $KMnO_4$ + 0.1 mol/l H_2SO_4. 45, 145, 245, 345, 445, 545, 645, 745 and 845 s from bottom to top. R_1, Rayleigh scattering. R_2, Raman scattering of water. Insert: plot of fluorescent intensity vs. time.

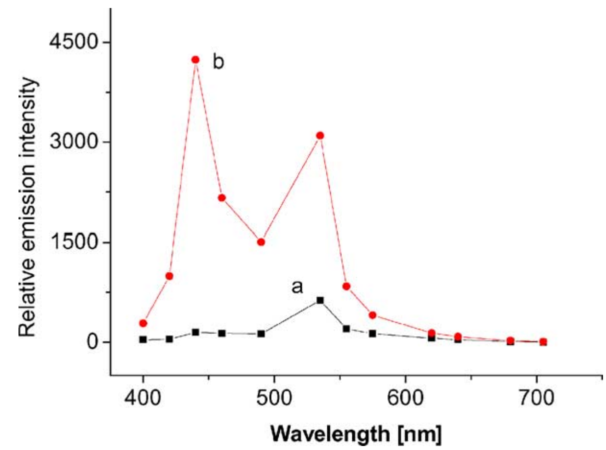


Fig. 7. CL spectra of $KMnO_4$–Na_2SO_3–H_2SO_4 (a) and noscapine-$KMnO_4$–Na_2SO_3–H_2SO_4 (b).

with maximum emission intensity at about 535 nm (Fig. 7a), which was similar to those measured with interference filters by Stauff and Jaeschke [30,39]. According to the suggestion reported in [18,30,31], the emitter was the exited sulfur dioxide. Thus, the oxidization product of HSO_3^- by the oxidized form of noscapine should be $HSO_3^{\bullet}$ radical. Two $HSO_3^{\bullet}$ radicals then combined to produce $S_2O_6^{2-}$, which gave the excited intermediate product SO_2^* with an emission when it returned to its ground state [18].

In noscapine–$KMnO_4$–Na_2SO_3–H_2SO_4 system, the CL spectrum showed two bands around 490–620 nm and 400–490, respectively (Fig. 7b). The new maximum CL emission intensity occurred at about 440 nm, coinciding with the maximum fluorescence emission wavelength of the oxidized form of noscapine. Thus SO_2^* and the excited oxidized noscapine species might be the emitters in this system. The later could be produced from the oxidation of $[\text{noscapine}]_{ox}^{\bullet}$ by MnO_4^-. The mechanism could be expressed as follows:

$$\text{noscapine} + MnO_4^- \rightarrow [\text{noscapine}]_{ox}^{+} + \text{manganese complex}$$

$$[\text{noscapine}]_{ox}^{+} + HSO_3^- \rightarrow HSO_3^{\bullet} + [\text{noscapine}]_{ox}^{\bullet}$$

$$2HSO_3^{\bullet} \rightarrow S_2O_6^{2-} + 2H^+$$

$$S_2O_6^{2-} \rightarrow SO_4^{2-} + SO_2^*$$

$$SO_2^* \rightarrow SO_2 + h\nu\,(535\,\text{nm})$$

$$[\text{noscapine}]_{ox}^{\bullet} + MnO_4^- \rightarrow [\text{noscapine}]_{ox}^{+*} + \text{manganese complex}$$

$$[\text{noscapine}]_{ox}^{+*} \rightarrow [\text{noscapine}]_{ox}^{+} + h\nu(440\,\text{nm})$$

4. Conclusions

The weak CL reaction of sulfite and acidic $KMnO_4$ can be enhanced significantly in the presence of noscapine. The sensitizing effect of noscapine on the reaction is due to the excited oxidized form of noscapine molecule and SO_2^*, which are produced from the reaction of sulfite and the oxidation product of noscapine by $KMnO_4$. Based on the sensitizing effect a CL method for determination of noscapine is purposed. This method is simple, highly sensitive and selective, and can be satisfactorily used in the determination of noscapine in practical sample.

Acknowledgements

This project was supported by the National Natural Science Foundation of China (No. 20275017, 90206037), the Specialized Research Funds for the Doctoral Program of Higher Education (200028403) and the Excellent Young Teachers from Chinese Ministry of Education, the Science Foundation of Jiangsu (No. BS2001063) and the Key Project of Cancer Institute of Jiangsu Province.

References

[1] United Nations, in: Recommended methods for testing opium/crude morphine, United Nations, New York, 1987, p. 4.
[2] M.C. Gerald, Pharmacology, an Introduction to Drugs, Prentice-hall, Englewood Cliffs, NJ, 1974, p. 241.
[3] H.C. Joshi, J. Zhou, Drugnews Perspect. 13 (2000) 543.
[4] J.W. Landen, R. Lang, S.J. McMahon, N.M. Rusan, A.M. Yvon, A.W. Adams, M.D. Sorcinelli, R. Campbell, P. Bonaccorsi, J.C. Ansel, D.R. Archer, P. Wadsworth, C.A. Armstrong, H.C. Joshi, Cancer Res. 62 (2002) 4109.
[5] R. Lang, J. Landen, S. McMahon, A. Adams, R. Campbell, P. Bonaccorsi, D. Archer, J. Ansel, H. Joshi, C. Armstrong, J. Invest. Dermatol. 117 (2001) 568.
[6] British Pharmacopoeia, vol. 1, HMSO, London, 1980, p. 311.
[7] British Pharmacopoeia, vol. 1, HMSO, London, 1993, p. 458.
[8] B. Saad, S.M. Sultan, F.E.O. Suliman, Talanta 44 (1997) 53.
[9] M. Johansson, D. Westerlund, J. Chromatogr. 452 (1988) 241.
[10] K.O. Chu, K.C. Tin, Anal. Lett. 31 (1998) 1879.
[11] D.F. Chollet, C. Ruols, V. Arnera, J. Chromatogr. B 701 (1997) 81.
[12] L. Krenn, S. Glantschnig, U. Sorgner, Chromatographia 47 (1998) 21.
[13] Y.P. Chen, P. Wang, C.Y. Shaw, B.L. Chang, J. Food Drug Anal. 7 (1999) 13.
[14] K. Janhunen, M.D. Cole, Forensic Sci. Int. 102 (1999) 1.
[15] X. Wang, D.R. Bobbitt, Anal. Chim. Acta 383 (1999) 213.
[16] P.B. Oldham, M.E. McCarroll, L.B. McGown, I.M. Warner, Anal. Chem. 72 (2000) 197R.
[17] L.J. Kricka, Biolumin. Chemilum. PT C Methods Enzymol. 305 (2000) 333.
[18] I.M. Psarellis, N.T. Deftereos, E.G. Sarantonis, A.C. Calokerinos, Anal. Chim. Acta 294 (1994) 27.
[19] L.Q. Li, Y.M. Zhou, X.J. Tao, M.L. Feng, J.R. Lu, Fenxi Huaxue 27 (1999) 1333.
[20] R.W. Abbott, A. Townshend, R. Gill, Analyst 111 (1986) 635.
[21] N.W. Barnett, S.W. Lewis, D.J. Tucker, Fresenius J. Anal. Chem. 355 (1996) 591.
[22] N.W. Barnett, C.E. Lenehan, S.W. Lewis, D.J. Tucker, K.M. Essery, Analyst 123 (1998) 601.
[23] I.B. Agater, R.A. Jewsbury, Anal. Chim. Acta 356 (1997) 289.
[24] B.J. Hindson, N.W. Barnett, Anal. Chim. Acta 445 (2001) 1.
[25] N.W. Barnett, D.G. Rolfe, T.A. Bowser, T.W. Paton, Anal. Chim. Acta 282 (1993) 551.
[26] A. Campiglio, Analyst 123 (1998) 1053.
[27] N.W. Barnett, B.J. Hindson, P. Jones, T.A. Smith, Anal. Chim. Acta 451 (2002) 181.
[28] H.Y. Qi, M.L. Yang, M.L. Feng, J.R. Lu, Chem. Res. Chin. Univ. 13 (1997) 229.
[29] Y.H. He, Y.Y. Xue, M.L. Feng, J.R. Lu, Fenxi Huaxue 26 (1998) 1136.
[30] M. Kato, M. Yamada, S. Suzuki, Anal. Chem. 56 (1984) 2529.
[31] F. Meixner, W. Jaeschke, Fresenius' Z. Anal. Chem. 317 (1984) 343.
[32] X.L. Liu, Z.K. He, Q.Y. Luo, X.M. Yu, J.P. Huang, R. Liu, Y.E. Zeng, Fenxi Huaxue 23 (1995) 652.
[33] A. Townshend, R.A. Wheatley, Analyst 123 (1998) 267.
[34] C.Q. Zhu, L. Wang, Y.X. Li, F. Gao, Fenxi Huaxue 25 (1997) 387.
[35] S. Klemenc, Forensic Sci. Int. 108 (2000) 45.
[36] Y.F. Zhuang, S.C. Zhang, J.S. Yu, H.X. Ju, Anal. Bioanal. Chem. 375 (2003) 281.
[37] J.L. Lopez Paz, A. Townshend, Anal. Commun. 33 (1996) 31.
[38] The Note of Chinese Pharmacopoeia, Beijing, 1990, p. 613.
[39] J. Stauff, W.Z. Jaeschke, Naturforsch. B 33B (1978) 293.