March 2009 Volume 8 Issue 1

Trade Science Inc.

Analytical CHEMISTRY

An Indian Journal

Full Paper

ACAIJ, 8(1) 2009 [09-13]

Kinetic determination of aminopyrine by using the bifurcation point in Mn(II)-catalyzed B-Z oscillating chemical system

Jinzhang Gao*, Miao Guo, Jie Wang, Jie Ren, Wu Yang

College of Chemistry and Chemical Engineering, Northwest Normal University, Lanzhou-730070, (P. R.CHINA)

E-mail : jzgao@nwnu.edu.cn

Received: 16th December, 2008 ; Accepted: 21sr December, 2008

ABSTRACT

A novel and convenient method with good selectivity and high sensitivity was used to determine aminopyrine. The method is based on the perturbation with different amounts of aminopyrine on the Mn(II)-catalyzed oscillating system, which is being in a non-equilibrium stationary state close to the bifurcation point between non-oscillatory and oscillatory state, using a continuous-flow stirred tank reactor(CSTR). A well linear relationship between the potential difference (i.e., $\Delta E_m = E_p - E_b$) and the negative logarithm of aminopyrine amount was found to be in the range of 7.94×10^{-5}~5.62×10^{-8} mol L^{-1} and a lower detection limit of 7.25×10^{-9} mol L^{-1} was also obtained. To estimate the reliability, some otherl methods (including regular oscillation) were compared with it together.

KEYWORDS

Oscillating chemical reaction;
Aminopyrine;
APP;
CSTR.

1. INTRODUCTION

Oscillating chemical reactions are complex nonlinear systems, which can exhibit different dynamic regimes such as regular and irregular oscillations, as well as chaos under different conditions. Such sorts of behavior in chemical and biological systems offer many choices for application to analytical chemistry. So far, regular oscillating profiles have been applied widely for the determination of organic and inorganic substances by using an analyte pulse perturbation technique (APP) in a continuously stirred tank reactor (CSTR)[1,2]. The basic principle is that adding an analyte to an oscillating reaction to perturb the oscillating profiles (e.g., period and amplitude) first, then to calculate the relationship between the change of signal and the amount of analyte added. In other words, kinetic analytical methods are to study an ability of analyte to change kinetic parameters of chemical reactions. In view of the fact that any parameters of kinetic reactions, whose change caused by adding analyte was able to be a quantitative relationship with the amounts of analyte added, could be adopted for the analytical purpose. For this reason, Perez-Bendito's group[3,4] and Strizhak's group[5,6] investigated theoretically the largest Lyapunov exponent in the transient chaotic regime with the B-Z (Belousov-Zhabotinsky) oscillating system and developed a new analytical method with very high sensitivity (detection limit $\leq 10^{-12}$ mol L^{-1}). Gao et al[7,8] reported that a modified B-Z oscillating chemical system by sulfide is very sensitive to the trace amounts of some metal ions. All of facts demonstrated again that the oscillating chemical reaction as a novel analytical technique has been made a long progress, and applied successfully to the determination of organic and inorganic substances. Compared to instrumental analysis, this technique has rep-

resented many advantages such as a simple set-up with ease of operation, a wide linear range and a lower detection limit and so on.

Recently, Vukojevic and Pejic et al[9-11] studied the characteristics of a non-equilibrium stationary state close to the bifurcation point between non-oscillatory and oscillatory state, and proposed successfully a novel kinetic method for the determination of organic compounds and inorganic ions. In fact, the vicinity of a bifurcation point of non-equilibrium system gestates a fluctuation, which is very sensitive to the surrounding change. For this reason, it can be used in analytical chemistry. To assess the validity in the present paper we consider aminopyrine as an analyte to examine reaction conditions in detail and satisfactory results were obtained. In addition, aminopyrine is an important material in pharmaceutical synthesis. A convenient method for its determination with good selectivity and high sensitivity should be developed, too.

2. EXPERIMENTAL

2.1. Reagents

All chemicals used were of analytical grade and doubly distilled water was used throughout to prepare solutions. Solutions of $KBrO_3$ (0.15 mol L^{-1}), $MnSO_4$ (0.003 mol L^{-1}) were prepared in 0.65 mol L^{-1} sulfuric acid solution. Ethyl acetoacetate (0.02 mol L^{-1}) was prepared in distilled water. A stock standard solution of aminopyrine (0.005 mol L^{-1}) was prepared from fresh purified aminopyrine and stored in refrigeratory. Working solutions were prepared daily by appropriate dilution. Aminopyrine injection (99.99%; Zhengzhou Lingrui Pharmaceutical Co.) was diluted to 2.25×10^{-5} mol L^{-1} and stored in refrigeratory. Analytes such as aminopyrine, caffeine tablets and aminopyrine tablets were dissolved respectively in distilled water and then stored in refrigeratory.

2.2. Apparatus

As shown in our previous work[2], the experimental set-up consisted of a 50 ml glass vessel fitted with a CS-501 thermostat and an ML-902 magnetic stirrer (Shanghai Pujiang Analytical Instrumental Factory, China). A CHI-832 (CHI, USA) electrochemistry analyzer was directly connected to the reactor through two Pt electrodes in which one is as working electrode and the other as counter electrode, and a K_2SO_4 reference electrode to record the potential changes. The reactants were fed by a Type Lead-1 peristaltic pump (Lange Corporation, China). A syringe was also used to inject different amounts of aminopyrine into the reaction system. A Model 2550 UV Spectrophotometer (Shanghai, China) was used to detect aminopyrine in order to ensure the accuracy of the proposed method.

2.3. Procedure

A mixture solution containing 5.0 mL of 0.02 mol L^{-1} ethyl acetoacetate, 5.0 mL of 0.003 mol L^{-1} $MnSO_4$ and 5.0mL of 0.15 mol L^{-1} $KBrO_3$ was added firstly into the reactor, and then the peristaltic pump was opened with a constant flow rate of 1.4 mL/min for each channel. The magnetic stirring rate was 800 rpm and the mixture solution was maintained at 60.0^0C. The electrodes were immersed into the reaction media and the data acquisition started. At that time a regular steady oscillation profile was observed. With decreasing the temperature, the amplitude of oscillation becomes small gradually and disappears eventually. That is to say, a stable dynamic structure reached. And then variable concentrations of aminopyrine were injected into system sequentially and the potential change was recorded.

3. RESULTS AND DISCUSSION

3.1. Optimization of experimental conditions

At first, we must know where the bifurcation point is, that is, a critical value between non-oscillatory phase and oscillatory phase in far-from-equilibrium dynamic systems. Theoretically, changing any dynamic parameters could make the oscillating profile both in amplitude and period from oscillatory to non-oscillatory phase. Temperature, commonly, was chosen as a preferred variable. The fall of temperature would cause clearly the amplitude decreased and the period prolonged, which were shown in figure 1, (notice that the whole process was located in ranging from 60^0C to 28^0C, here only showing a part), where the x-axis stands for time (minute) and the y-axis for potential (mV). Based on the data in figure 1, a plot of potentials (both maximum and minimum) versus temperature was made as shown in figure 2. It is easy to understand that for a

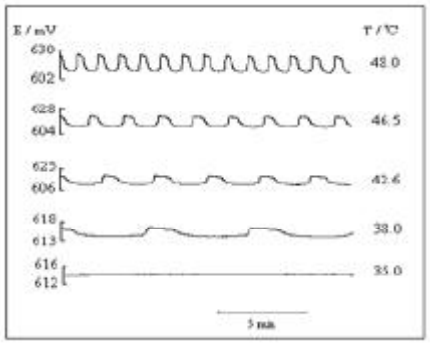

Figure 1: Time series showing stable dynamic structures observed in the B-Z reaction at different temperatures. Common conditions:[$KBrO_3$] = 0.15mol L^{-1},[$MnSO_4$] = 0.003mol L^{-1}, [Ethyl acetoacetate] = 0.02mol L^{-1},[H_2SO_4] = 0.45mol L^{-1}

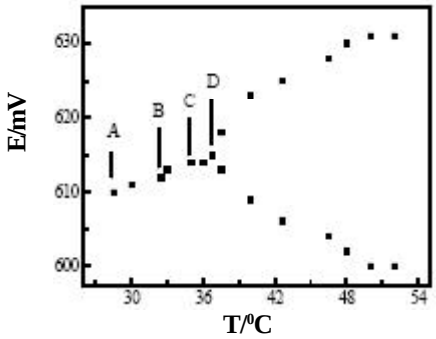

Figure 2: Bifurcation diagram for temperature as control parameter. Arrowheads indicate the temperatures (A=28.5°C, B=32.5°C, C=35.0°C and D=36.8°C) at which aminopyrine (C=3.16×10^{-6} mol L^{-1}) was injected respectively

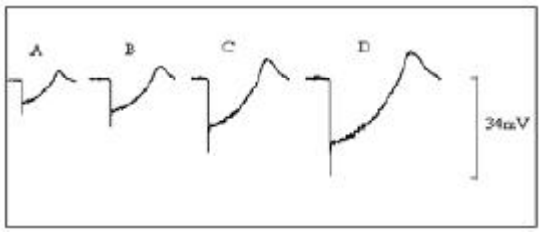

Figure 3: The perturbations of aminopyrine (C=3.16×10^{-6} mol L^{-1}) at different temperatures(A=28.5°C, B=32.5°C, C=35.0°C and D=36.8°C) on the non-equilibrium stationary state of B-Z system

regular oscillating profile there are two potential points (i.e., the highest and the lowest values); for a non-oscillating straight-line only one point can be acquired, meaning that the bifurcation point should be limited the range from 36.8°C to 28.5°C. Then, adding aminopyrine into

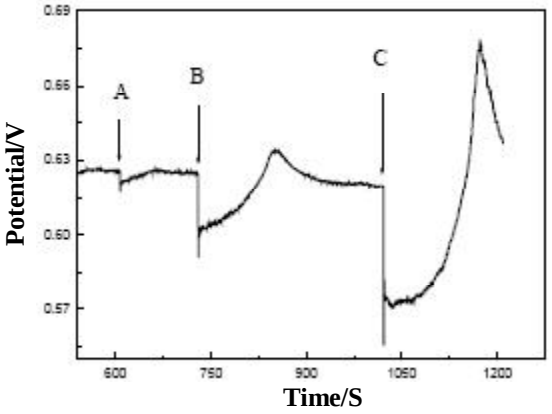

Figure 4: The influence of different concentrations of aminopyrine on the stable stationary state at T=36.8°C. A, B and C denote the injection concentration of aminopyrine are 9.33×10^{-8} mol L^{-1}, 3.16×10^{-6} mol L^{-1} and 7.94×10^{-5} mol L^{-1} respectively

the non-oscillating system at different temperature to find the most sensitive point, that is, the non-equilibrium stationary state close to the bifurcation point. Those tests have been shown in figure 2 by arrows, for example, T=28.5°C, 32.5°C, 35.0°C and 36.8°C. Results indicated that the most sensitive point appears at 36.8°C. In the same way, if a plot of potential change versus temperature was made, the similar result could be observed in figure 3. It is worth notice that over 36.8°C the stability of system would decrease sharply. Thus, in this study the optimal temperature for determining aminopyrine should choose at T£½36.8°C.

3.2. Determination of aminopyrine

The vicinity of bifurcation point for a non-equilibrium system is very sensitive to analyte although it seems to be a non-oscillating straight-line. In other words, this is the optimum injecting position for determining aminopyrine. Just as shown in figure 4, using different concentrations of aminopyrine (A= 9.33×10^{-8} mol L^{-1}, B=3.16×10^{-6} mol L^{-1}, and C= 7.94×10^{-5}mol L^{-1}, respectively) to perturb the system, the directly proportional responses were obtained. For ease of representation, the symbol of E_b stands for the potential before perturbation, which can be considered as a baseline due to being a constant, E_p for the potential after perturbation. It was found that the potential difference after and before perturbation, $\Delta E_m = E_p - E_b$, is proportional to the negative logarithm of aminopyrine concentration very well in the range of 7.94×10^{-5} -5.62×10^{-8}mol L^{-1}

Full Paper

(see figure 5). The linear relationship can be expressed by the following regression equation:

ΔE_m (mV) = 130.112-17.736(-log C)(R=0.9993, N=11)

The proposed method offers a high sample throughput (25 samples h^{-1}) and a lower detection limit of 7.25×10^{-9}mol L^{-1}.

3.3. Interferences

To assess the selectivity of the proposed method, the interferences of some foreign species were investigated, including inorganic ions, organic alcohols and acids with small molecular weight, as well as antipyrine in the presence of 9.0×10^{-8} mol L^{-1} aminopyrine with an error <±5 %. Results are listed in TABLE 1. It can be seen that there was no effect on the stable non-equilibrium system for commonly inorganic ions (e.g., 1000-fold of cations or 800-fold of anions). Less than 50-fold of Cl^-, Br^-, and I^- ions have also no effect on the determination of aminopyrine. Antipyrine and barbituric acid are tolerated to be less than 10-fold.

3.4. Comparison with other methods

Actually, there are many methods can be used to determine the aminopyrine, such as HPLC[12], spectrophotometry[13] and caplillary electrophoresis-electrochemical detection[14] etc. Results are given in TABLE 2. Based on their sensitivities and linear ranges, it can be said that the proposed method is better one in the routine analysis.

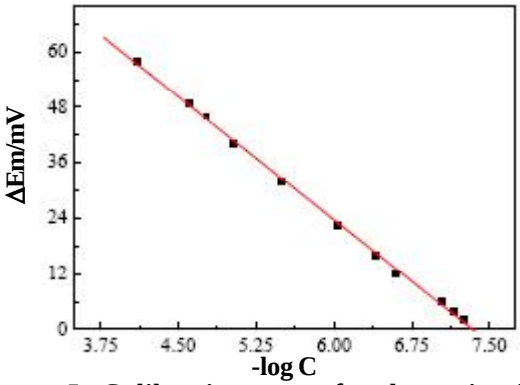

Figure 5: Calibration curve for determination of amidopyrine

3.5. Sample analysis

Using the proposed method to examine six of aminopyrine injections, satisfactory results are obtained in TABLE 3. The recoveries were limited in the range from 97.11% to 102.5%.

Several pharmaceutical dosage forms including aminopyrine injection, aminopyrine, caffeine tablets and aminopyrine tablets were also detected, respectively. Each sample was determined repeatedly for 5 times. Results in TABLE 4 recommended again that the pro-

TABLE 1: Effect of foreign species on the determination of 9.0×10^{-8}mol L^{-1} aminopyrine

Foreign species	Tolerated ratio (foreign/ aminopyrine)
Ca^{2+}, Ba^{2+}, Mg^{2+}, Zn^{2+}, Fe^{3+}, Al^{3+}, La^{3+}	1000
SO_4^{2-}, PO_4^{3-}, HPO_4^{2-}, $H_2PO_4^-$, NO_3^-	800
Cl^-, Br^-, I^-	50
Methanol, Ethanol, Formic acid, Acetic acid	20
Antipyrine, Barbituric acid	10

TABLE 2: Comparison with other analytical methods for determining aminopyrine

Method	Linear range (mol L^{-1})	Reference
High-performance liquid chromatography	8.66×10^{-7}~ 4.33×10^{-5}	12
Spectrophotometry	2.16×10^{-5} ~ 1.08×10^{-4}	13
Caplillary electrophoresis-electrochemical detection	5.00×10^{-5} ~ 1.00×10^{-2}	14
Regular oscillating chemical reaction	9.55×10^{-6} ~ 8.32×10^{-4}	Present work
The proposed method	5.62×10^{-8} ~7.94×10^{-5}	Present work

TABLE 3: Recovery analysis of sample

Sample	Original (mol L^{-1})	Added (mol L^{-1})	Found (mol L^{-1})	Recovery (%)
1	4.50×10^{-7}	0	4.37×10^{-7}	97.11
2	4.50×10^{-7}	2.00×10^{-6}	2.42×10^{-6}	98.78
3	4.50×10^{-7}	4.00×10^{-6}	4.56×10^{-6}	102.5
4	4.50×10^{-7}	6.00×10^{-6}	$6.43\times10^{-6-6}$	99.69
5	4.50×10^{-7}	8.00×10^{-6}	8.50×10^{-6}	100.6

TABLE 4: Determination of aminopyrine in three pharmaceuticals by using spectrophotometry and proposed method

Sample	Original quantity	Proposed method(N=5)		Spectrophotometry(N=5)	
		Determine result	RSD	Determine result	RSD
Aminopyrine injection	50.00mg·mL^{-1}	49.20 mg·mL^{-1}	1.3%	49.00 mg·mL^{-1}	1.8%
Aminopyrine tablet	150.0 mg	148.7 mg	2.4%	149.1 mg·	2.2%
Aminopyrine and caffeine tablet	150.0 mg	148.9 mg	2.8%	148.8 mg·	2.6%

posed method have higher sensitivity and good reproducibility.

4. CONCLUSION

The proposed method to examine aminopyrine offers a wide linear range of 7.94×10^{-5}~5.62×10^{-8} mol L^{-1}, a low detection limit of 7.25×10^{-9} mol L^{-1} and high sample throughput(25 sample h^{-1}). Results indicated that the bifurcation point in Mn(II)-catalyzed B-Z oscillating chemical system can be considered as an analytical technique in real samples. Relative to the instrumental analysis, the equipment used in the proposed method is less expensive. Moreover, larger linear range and lower detection limit could satisfy the need of common determination.

ACKNOWLEDGMENTS

This work was supported in part by the National Natural Science Foundation (20873101), the Project of International Cooperation between China and Ukraine (043-05), and the Project of KJCXGC-01 of Northwest Normal University, China.

REFERENCES

[1] R.Jimenez-Prieto, M.Silva, D.Perez-Bendito; Analyst, **123**, 1R-8R **(1998)**.
[2] J.Z.Gao; Pakistan Journal of Biological Sciences, **8(4)**, 512-519 **(2005)**.
[3] R.Jimenez-Prieto, M.Silva, D.Perez-Bendito; Analyst, **121**, 563-566 **(1996)**.
[4] R.Jimenez-Prieto, M.Silva, D.Perez-Bendito; Analyst, **122**, 287-292 **(1997)**.
[5] O.Z.Didenko, P.E.Strizhak; Chemical Physics Letters, **340**, 55-61 **(2001)**.
[6] P.E.Strizhak, O.Z.Didenko, T.S.Ivashchenko; Analytica Chimica Acta, **428**, 15-21 **(2001)**.
[7] J.Z.Gao, H.Chen, H.X.Dai, D.Y.Lv, J.Ren, L.Wang, W.Yang; Analytica Chimica Acta, **571**, 150-155 **(2006)**.
[8] H.Chen, W.Yang, H.X.Dai, X.X.Wei, J.Qu, J.Z.Gao; Chinese Chemical Letters, **17**, 1221-1224 **(2006)**.
[9] V.B.Vukojević, N.D.Pejic, D.R.Stanisavljev, S.R.Anic, L.Z.Kolar-Anic; Analyst, **124**, 147-152 **(1999)**.
[10] N.D.Pejic, L.Z.Kolar-Anic, S.R.Anic, D.R. Stanisavljev; Journal of Pharmaceutical and Biomedical Analysis, **41**, 610-615 **(2006)**.
[11] N.D.Pejic, S.M.Blagojevic, S.R.Anic, V.B. Vukojevic, M.D.Mijatovic, J.S.Ciric, Z.S.Markovic, S.D.Markovic, L.Z.Kolar-Anic; Analytica Chimica Acta, **582**, 367-374 **(2007)**.
[12] M.J.D'souza, M.A.Zemaitis, G.J.Burckart, R. Venkataramanan; Journal of Chromatography, **421**, 198-205 **(1987)**.
[13] C.Y.Wang, L.T.Zhang, Y.He, A.H.Zhang, Y.M. Zhou, R.H.Chen, Z.X.Zhou; Spectroscopy and Spectral Analysis(Ch), **19**, 758-759 **(1999)**.
[14] W.H.Zhou, J.Liu, E.K.Wang; Journal of Chromatography A, **715**, 355-360 **(1995)**.