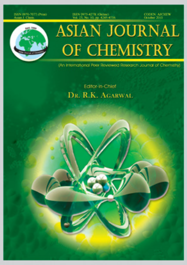
Asian Journal of Chemistry; Vol. 24, No. 11 (2012), 4847-4850

ASIAN JOURNAL OF CHEMISTRY

www.asianjournalofchemistry.co.in



Differential Electrolytic Potentiometry: A Detector for Flow Injection/Sequential Analysis in Complexation Reactions

SAFWAN M.A. FRAIHAT[1,*] and ABDALLA M.S. ABULKIBASH[2]

[1]Hamdi Mango Center for Scientific Research, Jordan University, Amman 11942, Jordan
[2]Department of Chemistry, King Fahd University of Petroleun and Minerals, Dahran 31261, Kingdom of Saudi Arabia

*Corresponding author: E-mail: s.fraihat@ju.edu.jo

(*Received*: 1 February 2011; *Accepted*: 23 May 2012) AJC-11510

Differential electrolytic potentiometry is applied as an indicating system for the determination of ciprofloxacin using flow injection/ sequential injection analysis configuration. The behaviour of silver electrodes, platinum electrodes, silver amalgam electrodes and platinum amalgam electrodes has been investigated. The optimim conditions of type of electrodes, flow rate, volume of sample, the magnitude of the current, the coil length, the concentration of the reagent and the concentration of sulphuric acid all has been investigated. A normal calibration curve is applicable for the determination of ciprofloxacin in formulated drugs has been obtained. The advantage of differential electrolytic potentiometry as a detector for flow injection or sequential analysis is reported.

Key Words: Differential electrolytic potentiometry, Flow injection, Sequential analysis, Complexation.

INTRODUCTION

Differential electrolytic potentiometry (DEP) is a technique used to locate the end-point in titrimetric reactions and to study the electrode processes. It consists of passing a heavily stabilized current in two identical electrodes and measuring the potential difference (ΔE) between them during the course of the titration. At the end-point a sharp peak is resulted which represents the first differential of the zero current potentiometric curve. The end point is easily located from the tip of this peak. The differential electrolytic potentiometry technique does not require a reference electrode, whose salt bridge is causing various difficulties especially if non-aqueous systems are considered. Moreover, polarization usually enhances the response of the electrodes which will remain active during the course of the titration and equilibrate in a short time. This introduces differential electrolytic potentiometry as a suitable detector for most of the titrimetric reactions, flow injection analysis (FIA), sequential injection analysis (SIA) and possibly for ion-chromatography or even high performance liquid chromatography.

Differential electrolytic potentiometry has been applied to all types of ion-combination and redox reactions in aqueous media using different types of electrodes. Silver electrodes and silver-silver halide electrodes have been found to be suitable for precipitation reactions while antimony oxide electrodes for acid-base reactions[1-7]. Platinum electrodes have been applied in oxidation-reduction reactions[8-10] and gold amalgam electrodes are appropriate for complexation reactions[11,12].

Differential electrolytic potentiometry has also been applied to different types of titrimetric reactions in non-aqueous media using various types of solid electrodes[13-17].

In an attempt to apply differential electrolytic potentiometry as a detector for ordinary flow injection analysis systems a set up that uses a computerized motor-driven injector has been designed and applied for precipitation reactions[18-20]. However, this system was not practical enough to allow for the developments of rapid analytical procedures. This system was replaced with FIA 3500 which is more reliable and delivers precise volumes which was found to be extremely important for the application of differential electrolytic potentiometry. This technique has not been applied yet as a detector in normal flow injection analysis and sequential injection analysis instruments.

Ciprofloxacin [l-cyclopropyl-6-fluoro-l,4-dihydro-4-oxo-7-(l-piperazinyl)quinolone-3-carboxylic acid] is a broad-spectrum antibiotic which is effective against Gram-positive and Gram-negative bacteria. This antibiotic is usually used in the treatment of respiratory as well as urinary tract infections, sexually transmitted diseases and gastro-intestinal[21-24].

Ciprofloxacin has been determined by applying different methods. These methods include differential pulse polarography and cathodic stripping voltammetry[25-27]. Chromatographic methods[28-30], a potentiometric method based on preparing a coated wire ion-selective electrode has been developed for the determination of ciprofloxacin[31]. A flow injection spectrophotometric method has been reported for the determination of ciprofloxacin using iron(III) as a complexing agent in sulfuric acid[32]. A conductometric titration has been applied for the determination of ciprofloxacin which was titrated with silver nitrate[33]. Ciprofloxacin has been determined by fluorescence detection using isocratic reversed-phase HPLC[34]. Flow injection combined with chemiluminescence has been applied for the determination of ciprofloxacin hydrochloride[35]. Electroanalytic methods like polarography[36], differential pulse polarography[37] have been employed for the determination of ciprofloxacin.

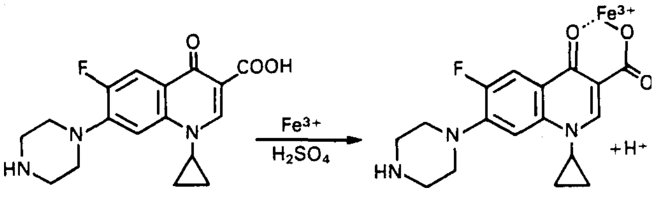
The technique of differential electrolytic potentiometry (DEP) has not applied so far for the determination of ciprofloxacin by FIA/SIA technique. This work describes the application of differential electrolytic potentiometry as a detector for FIA/SIA. For the first time, this combination is applied for the determination of ciprofloxacin.

EXPERIMENTAL

The FIALab 3500 (USA) was employed during this work. The apparatus consists of a syringe pump, a multi-position valve and a peristaltic pump. Three types of cells were fabricated from PTFE and Perspex glass. Precise grooves were made in these cells and fit in covers which have holes were made to accommodate the electrodes. The cell was connected to the flow injection analysis apparatus through plastic tubing in a way to allow these electrodes to meet the flowing solutions. The electrodes were connected to both the constant current source (Keithely 224 programmable current source) and to an XY recorder. The FIALab was interfaced with a pc.

RESULTS AND DISCUSSION

Ciprofloxacin reacts with iron(III) in a 1:1 ratio to form a complex and the reaction is reported to be fast[32]. Iron(III) is coordinated with the active carboxylic acid and the adjacent keto group in the 3- and 4-position respectively, forming six-membered ring (**Scheme-I**).



Scheme-I

In a study, ciprofloxacin has been found to bind with iron(II) and iron(III) as bidentate ligand through the oxygen atom of the carbonyl group and one oxygen atom in the carboxylate group[38].

Several experiments have been carried to find the appropriate manifold to be followed during this work. Different concentrations of Fe(III) as well as different concentrations of sulfuric acid were used with different manifolds. However, it was found that coupling flow injection analysis with sequential injection analysis is the most appropriate configuration due to the fact that the reaction between Fe(III) and ciprofloxacin is expected to be fast and that necessitates passing the reaction mixture as fast as possible through the cell, other wise the difference in potential between the two electrodes will not be significant if it is measured towards the end of the reaction. A program was written based on the software provided by flow injection analysis lab. manufacturer and applied during optimization of coil length, sulfuric acid concentration, types of electrodes, flow rate and volume of sample. Responses of polarized silver electrodes, slver amalgam electrodes, platinum electrodes and platinum amalgam electrodes were all examined. The univariant method was employed to find the optimum conditions.

Fig. 1 represents the type of signal obtained when polarized silver electrodes were used as an indication system. Changing the flow rate, the path length, the concentration of sulphuric acid or the concentration of Fe(III) were found to have no significant effect on the resulting signal. However, on changing the current which was employed to polarize the silver electrodes, a slight improvement was observed especially on the heights of the peaks. Fig. 2 shows the peaks obtained at different values of the current employed to polarize silver electrodes using a flow rate of 300 uL/s and a concentration of 0.05 M sulphuric acid. It is obvious from these figures that the response of polarized silver electrodes was not satisfactory and therefore they can not be used as an indicating system for the reaction between ciprofloxacin and Fe(III). The resulting signal has increased slightly even at higher levels of currents.

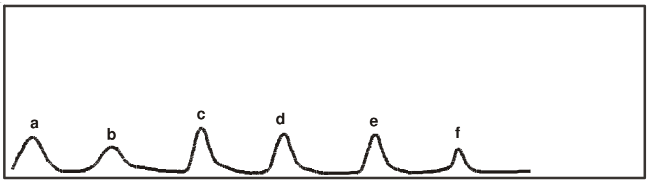


Fig. 1. Effect of path length on the height of the signal; a- 8 cm, b- 6 cm, c- 11 cm, d- 10 cm, e-9 cm, f-4 cm

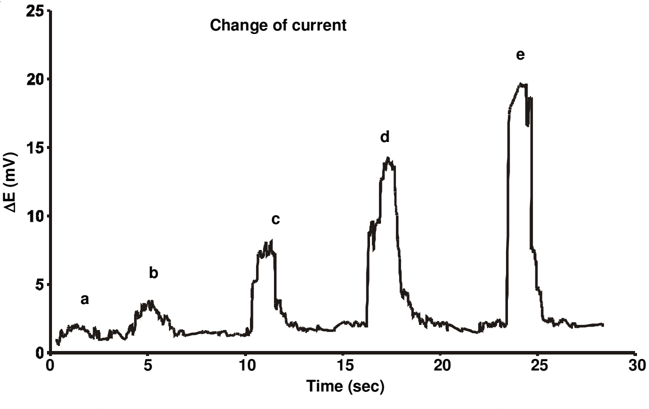


Fig. 2. Effect on changing the current on the signal of polarized silver electrodes; a- 1 μA, b- 3 μA, c- 7 μA, d- 10 μA, e- 15 μA

Platinum electrodes were also applied and different parameters to optimize their response were investigated. It was noted that the response of these electrodes was similar to that of silver electrodes. Fig. 3 showed that changing the current has no effect on the response of the platinum electrodes. Similar peaks were also obtained when the flow rate, the volume of the sample and the concentration of sulfuric acid were all changed, however no effect was noted on the resulting signal.

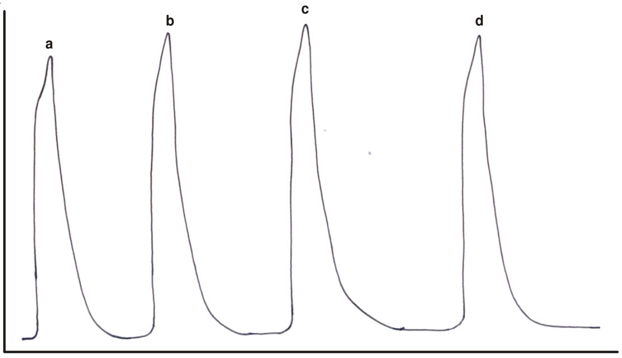


Fig. 3. Effect of changing the current on the response of platinum electrodes; a- 0.1 μA, b- 0.5 μA, c- 1.0 μA, d- 1.5 μA

Silver amalgam electrodes were also applied in order to investigate their behaviour. In fact these electrodes have been found to exhibit an excellent response during the titration of ciprofloxacin with iron(III)[39]. Two identical silver amalgam electrodes were polarized by a current of 0.50 μA and a coil length of 3.1 cm was used to connect the cell with the FIA/SIA instrument. Changing the flow rate or the volume of the sample or the length of the coil were found to have no effect on the height of the signal. However, a slight effect was observed by changing the current employed to polarize the electrodes (Fig. 4). Extensive investigation was made to explore the abnormal behaviour of silver amalgam electrodes. All the parameters that can affect the response of the electrodes were changed and studied. A solution of 0.10 M of potassium chloride was used as a carrier and at the same time as a supporting electrolyte to avoid the effect of sulphuric acid on the response of the silver amalgam electrodes. Different concentrations of ciprofloxacin were employed and it was noted that the height of the resulting signal for all of these solutions were almost the same. This could be attributed to the structure of the silver amalgam layer and a reaction between mercury in this layer and ciprofloxacin is inevitable. This point needs further investigation because silver amalgam is usually used in manufacturing the dental fillings and if such a reaction can occur, then those fillings could endanger the people's health.

As a result of the abnormal behaviour of the silver amalgam electrodes, it was decided to use platinum amalgam electrodes. Different parameters were considered such as the length of the coil, the flow rate, the volume of the sample, the concentration of the reagent and the concentration of the acid used as a carrier. Fig. 5 shows the effect of the coil length on the signal. It can be seen that any employed coil length was found to give a considerable signal compared to the results of the other electrodes like Ag, Pt or Ag/Hg which were studied earlier.

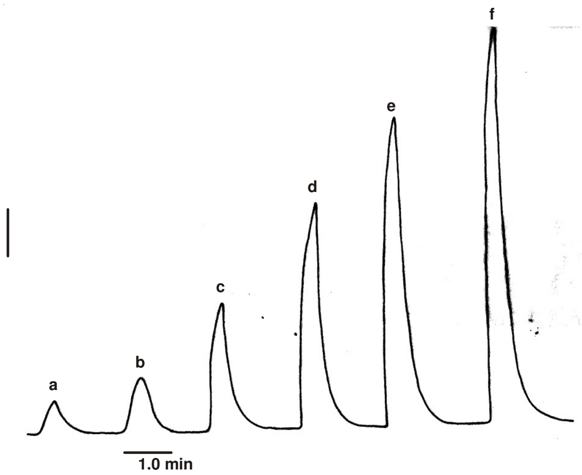


Fig. 4. Effect of changing the current: a- 0.1 μA, b- 0.2 μA, c- 0.5 μA, d- 1 μA, e- 5 μA and f- 10 μA

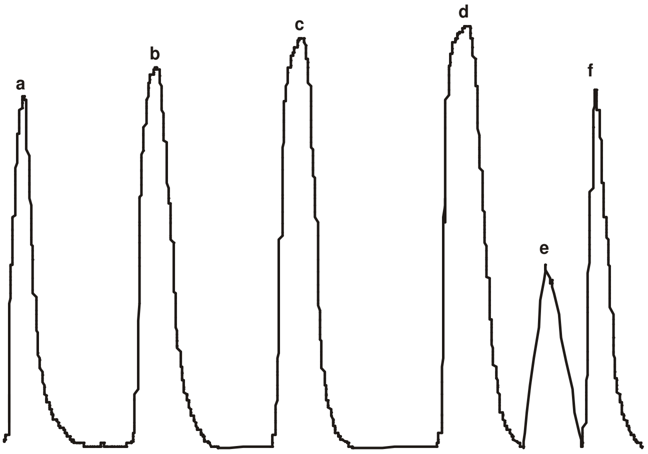


Fig. 5. Effect of changing the coil length a- 6 cm, b- 8.5 cm, c- 11 cm, d- 13; cm, e- 2 cm, f- 3.1 cm on the response of the Pt/Hg electrodes

The effect of changing the volume of the sample on the response of platinum amalgam electrodes has also been studied. This is obvious from Fig. 6 where the volume of the sample has found to exhibit a significant effect on the shape of the resulting differential curve. The effect of the current used to polarize these electrodes has also been investigated (Fig. 7).

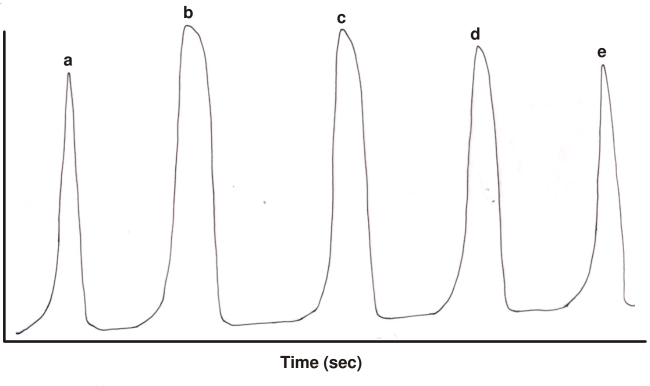


Fig. 6. Effect of changing the volume of the sample on the resulting signal of the cm. On the height of the signal obtained by Pt/Hg electrodes; a- 300 μL, b- 2000 μL, c-1500 μL, d- 100 μL, e- 600 μL

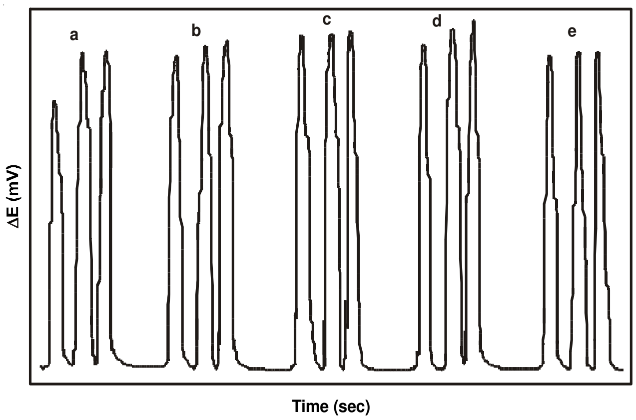


Fig. 7. Effect of changing the current on the resulting signal of Pt/Hg electrodes at a flow rate of 150 μL, sample volume of 300 μL, concentration of 0.01 M of Fe(III) and a sulfuric acid concentration of 0.05; a- 0.10 μA, b- 0.5 μA, c- 1.0 μA, d- 2.0 μA, e- 5.0 μA

Fig. 7 showed that an excellent signal has been obtained by applying different currents at constant parameters of flow rate, volume of sample and concentration of both the reagent and the sample. Peaks presented in Fig. 7 are typical peaks which are usually expected from the normal response of the polarized electrodes employed in the technique of differential electrolytic potentiometry.

The effect of changing the concentration of Fe(III) on the resulting signal of the polarized Pt/Hg electrodes is presented in Fig. 8. Changing the concentration of iron(III) was found to have a slight effect on the height of the resulting peaks and a concentration of 0.010 M Fe(III) was considered to be optimum for this work.

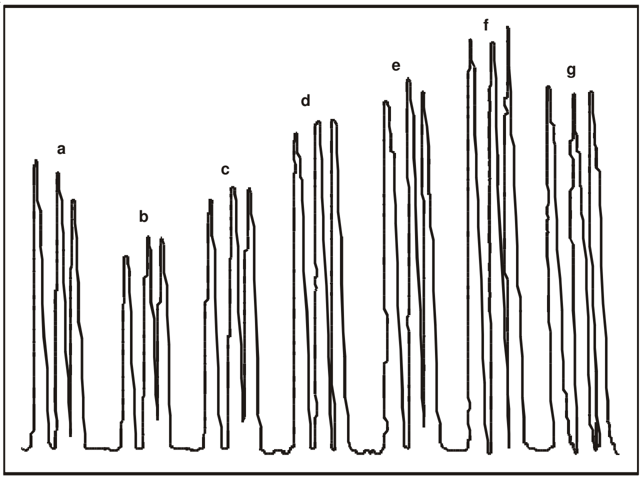


Fig. 8. Effect of changing the concentration of Fe(III) on the resulting signal of Pt/Hg electrodes at a current of 1 uA and acid concentration of 0.075 M and a flow rate of 300 uL; a- 0.05 M, b- 0.04 M, c- 0.03 M, d- 0.02 M, e- 0.010 M, f- 0.005 M, g- 0.002 M

The following are the optimum conditions for the FIA/SIA-DEP method for the complexation of ciprofloxacin and iron(III). The concentration of iron(III) was 0.01 M in 0.024 M H_2SO_4 and the concentration of ciprofloxacin was 500 ppm. The current employed was 0.5 μA and coil length was 3.1 cm. The flow rate was 150 μL and the volume of the sample was 300 μL. Fig. 9 shows the calibration curve using the optimized conditions above.

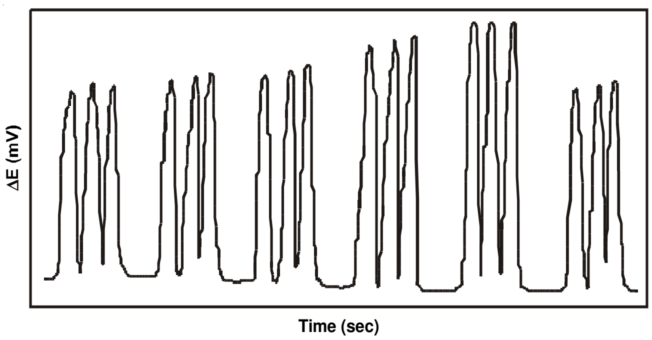


Fig. 9. Calibration curve using the optimized conditions

REFERENCES

1. E. Bishop and R.B. Dhaneshwer, *Analyst*, **87**, 207 (1962).
2. E. Bishop and R.B. Dhaneshwer, *Analyst*, **87**, 845 (1962).
3. E. Bishop and R.B. Dhaneshwer, *Anal. Chem.*, **36**, 726 (1964).
4. E. Bishop and G.D. Short, *Analyst*, **89**, 587 (1964).
5. E. Bishop and G.D. Short, *Analyst*, **87**, 467 (1962).
6. G.D. Short and E. Bishop, *Analyst*, **87**, 724 (1962).
7. G.D. Short and E. Bishop, *Analyst*, **89**, 415 (1964).
8. E. Bishop, *Mikrochim. Acta*, **44**, 619 (1956).
9. E. Bishop, *Analyst*, **83**, 212 (1958).
10. E. Bishop, *Analyst*, **85**, 422 (1960).
11. H.V. Malmstadt and E.R. Fett, *Anal. Chem.*, **27**, 1957 (1955).
12. R.G. Monk and K.C. Steed, *Anal. Chim. Acta*, **26**, 305 (1962).
13. A.M.S. Abdennabi and E. Bishop, *Analyst*, **107**, 1032 (1982).
14. E. Bishop and A.M.S. Abdennabi, *Analyst*, **108**, 1349 (1983).
15. A.M.S. Abdennabi and E. Bishop, *Analyst*, **108**, 71 (1983).
16. A.M.S. Abdennabi and M, Rashid, *Arabian J. Sci. Eng.*, **12**, 82 (1986).
17. A.M.S. Abdennabi and E. Bishop, *Analyst*, **108**, 1227 (1983).
18. A.M.S. Abdennabi and M.E. Koken, *Talanta*, **46**, 639 (1998).
19. A.M.S. Abdennabi, M.E. Koken and M.M. Khaled, *Anal. Chim. Acta*, **360**, 195 (1998).
20. A.M.S. Abulkibash, M. Khalid, M. Kok and S. Sultan, *Talanta*, **52**, 1139 (2000).
21. K. Grohe, H.-J. Zeiler and T.K. Metzger, *Liebigs Ann. Chem.*, **29**, 871 (1987).
22. K. Grohe, H.-J. Zeiler and T.K. Metzger, *Chem. Abstr.*, **99**, 53797h (1983).
23. K. Grohe, *Chem. Br.*, **28**, 34 (1992).
24. H.C. Neu, A. Percival and H. Lode, *Am. J. Med.*, **87**, 1 (1989).
25. A. Veber, M. Veber, F. Koq'ek and S. Gomiscek, *Acta Phann. Yug.*, **30**, 321 (1989).
26. L. Tekstor, M. Veber, M. Marolt-Gomiscek and S. Gomiscek, *Vestn. Slov. Kern. Drus.*, **36**, 25 (1989).
27. H.S. Lee, O.P. Zee, B.H. Woo and Y. Lee, *J. Environ. Sci. Health*, **26A**, 1253 (1991).
28. L. Pou-Clave, F. Campos-Barreda and C. Pascual-Mostaza, *J. Chromatogr. B*, **563**, 211 (1991).
29. I. Nilsson-Ehle, *J. Chromatogr. B*, **416**, 207 (1987).
30. H. Scholl, B. Weber and K. Schmidt, *J. Chromatogr. B*, **416**, 321 (1987).
31. H. Avsec and S. Gomiscek, *Anal. Chim. Acta*, **268**, 307 (1962).
32. S.M. Sultan and F.O. Suliman, *Analyst*, **117**, 1523 (1992).
33. F. Belal, M. Rizk, F.A. Aly and N.M. EI-Enany, *Chem-Anal (Warsaw)*, **44**, 763 (1999).
34. A. Zotou and N. Miltiadou, *J. Pharm. Biomed. Anal.*, **28**, 559 (2002).
35. Y. Liang, J. Li and Z. Zhang, *Fenxi Huaxue*, **25**, 1307 (1997).
36. S.M. Rizk, F. Belal, F.A. Ibrahim, S.M. Ahmed and Z.A. Sheribah, *Electroanalysis*, **12**, 531 (2000); **2**, 637 (1990).
37. P. O'Dea, A.C. García, A.J.M. Ordieres, P.T. Blanco and M.R. Smyth, *Electroanalysis*, **2**, 637 (1990).
38. J. AI-Mustafa and B. Tashtoush, *J. Coord. Chem.*, **56**, 113 (2003).
39. A.M.S. Abulkibash, S. Sultan. A.M. Al-Olyan and S.M. Al-Ghannam, *Talanta*, **61**, 239 (2003).