REPRINTS
Microwave-assisted synthesis and characterization of a new chelating resin functionalized with 2-aminothiazole: Application in trace level cadmium-mercury separation in biological samples

Suparna Dutta & Arabinda K Das

Department of Chemistry, University of Burdwan, Golapbag, Burdwan 713 104, India

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Chloromethylated polystyrene-divinylbenzene copolymer has been functionalized with 2-aminothiazole by using microwave irradiation. The resulting resin has been characterized by elemental analysis, thermogravimetric analysis, infrared spectra, water regain and metal sorption capacity. Various parameters like pH, equilibriation rate and sorption and desorption of metal ions, and effect of diverse ions have been studied. The maximum sorption capacities for Cd(II) and Hg(II) are 0.15 (pH 1) and 0.51 mmol g⁻¹ (pH 6) respectively. The concentration of Cd(II) was measured by flame atomic absorption spectrometry while Hg(II) was measured by cold vapor atomic absorption spectrometry. The limits of quantification (10σ) values were found to be 5.70 and 0.14 ng mL⁻¹ for Cd(II) and Hg(II) respectively. The procedure has been applied to the determination of cadmium and mercury in certified biological samples after their dissolution by microwave-assisted treatment. The method is simple, rapid and free from interference and can be used routinely.

Keywords: Solid phase extraction, 2-aminothiazole, Cd-Hg separation, AAS determination, microwave-assisted treatment biological samples.

IPC Code:A61N5/01; B01D15/00

There is current interest in developing chelating matrices¹⁻²⁰ and exploring them for metal enrichment. It stems partly due to higher selectivity of chelating resins for metal ions, which is also tunable by pH control. The focus of current research in this area is on the development of matrices of higher capacities. This can be achieved by increasing the number of chelating sites on the matrix as well as their accessibility. The former can be obtained by selecting ligands of small molecular size and latter by reducing the cross-linking of polymeric support.

Numerous chelating resins have been reported for their use in the separation of heavy metal ions²¹⁻²⁴. Chelating resin with S and N as donor atoms usually has excellent adsorption properties for soft metal ions like mercury, cadmium, lead, platinum, palladium and noble metal ions²⁵.

The presence of heavy metals in the environment is a cause of concern due to their acute and long-term toxicity. Cadmium and mercury present a major hazardous waste in the environment. Thus, removal of heavy metals is an area of increasing interest and there is a strong need for a reliable analytical procedure that can be applied to the determination and removal of these metals at very low concentrations. Guo et al.²⁶ have recently reported the preconcentration of Cd(II), Hg(II) and other metals from sea water and geological samples with 2-(methylthio) aniline functionalized immobilized XAD-2 resin²⁶,²⁷. Separation of Cd(II), Hg(II) and other metals has been carried out by using crosslinked poly [3-(methacyloylamino) propyl] dimethyl (3-sulphopropyl) ammonium hydroxide-co-2-acrylamido glycolic acid[P(MAAPDSA-co-AGCO)] by Rivas and Villegas²⁸. Reactive Yellow-2 dye-ligand immobilized chitosan membrane for removal of heavy metal ions like Cd(II), Hg(II) has been reported by Bayramoglu et al.²⁹

Now-a-days, instead of classical long time refluxing, few minutes' microwave-assisted organic synthesis are being carried out because of the short reaction time, environmentally clean process and operational simplicity³⁰,³¹. Several workers, to synthesize polymers, have used this technique but functionalization of polymeric matrix using this technique is rare³²,³³. Microwave-assisted digestion of different biological samples appears attractive as it is very fast³⁴ and can be coupled with instrumental techniques like AAS.

*For correspondence (E-mail: arabindakdas@rediffmail.com; Fax: +91-342-2557938)
Aim of this work is to develop a new solid phase extractor in a short time, which would facilitate the separation and removal of these toxic metal ions. In order to achieve this goal, chloromethylated DVB functionalized with 2-aminothiazole has been synthesized and applied successfully for the determination of cadmium and mercury in certified biological samples.

Experimental Procedure

Apparatus

Atomic absorption spectrometric measurements were carried out with a GBC AVANTA Atomic Absorption Spectrometer (model 908 BT) with the following conditions for cadmium: lamp current 3 mA, wavelength 228.8 nm and for mercury: lamp current 3 mA, wavelength 253.7 nm. FAAS was used for cadmium and CVAAS was used for mercury. The pH measurements were made with a Systronics digital pH meter (model 335). Infrared spectra were recorded on a 420 JASCO Fourier Transform Spectrometer. Sulphur and nitrogen contents of the resin were determined by using a Carlo-Erba CHNS-O EA 1108 Elemental Analyzer. Thermogravimetric analysis was done on a Shimadzu TG50/DT50 instrument. A domestic Samsung CE 2933 microwave oven with a 2450 MHz frequency magnetron and 900 W maximum power was employed to carry out the digestion of different biological samples in a polytetrafluoroethylene (PTFE) reactor with 115 mL internal volume, 1 cm cell wall thickness and hermetic screw caps.

Materials

Stock solutions of Cd(II) and Hg(II) were obtained from E.Merck (Germany) and working solutions were prepared by appropriate dilutions. 2-Aminothiazole (Lancaster, UK), Merrifield chloromethylated polystyrene resin (Fluka, crosslinked with 2% DVB; 200-400 mesh), thiourea (Merck Limited, Mumbai) were reagent grade and used as provided. All other chemicals used were of reagent grade. The glass apparatus used were soaked in 4 M nitric acid overnight and cleaned with double distilled water before use. The following reference materials were analysed: MA-M-2/TM mussel tissue (sample no. 325 of the International Atomic Energy Agency reference materials, Vienna, Austria), NIES 10c rice flour (NIES certified reference materials from the National Institute for Environmental Studies, Japan Environmental Agency) and Standard Reference Material (SRM) 1573 tomato leaves from National Bureau of Standards.

Methods

In order to carry out complete digestion of different types of biological samples, 100 mg to 150 mg of the material was treated in a 115 mL hermetically sealed PTFE reactor in the following way: first 4 mL aqua regia (450W, 2.5 min) was added followed by 3 mL H2O2 (450W, 4 min). After complete dissolution, each solution was diluted with double distilled water to a final volume of 25 mL.

Air-dried chloromethylated polystyrene copolymer (200-400 mesh, ~4.0 mmol Cl/g resin) containing 2% divinyl benzene was used as the starting material. The copolymer bead (500 mg) taken in a PTFE reactor, was treated with 2-aminothiazole (200 mg) in the presence of sodium carbonate (200 mg) in N, N-dimethyl formamide inside the microwave oven for different time span and power levels in order to establish the optimum condition for synthesis to obtain an orange-yellow polymer. The new resin thus obtained was washed thoroughly with DMF in order to remove excess ligand and then by 1 M HCl to remove excess base. Finally, it was washed with double distilled water, dried and preserved at room temperature for further use.

0.5 g of the resin was shaken with 100 mL of acid or alkali with different concentrations viz. with 1-12 M HNO3, HCl and NaOH solutions for 7 days. No significant change in nitrogen or sulphur content was observed after filtration and drying of the resin.

The dry resin was stirred in double distilled water for 48 h, then filtered off by suction, weighed, dried at 110 °C for 48 h and reweighed.

Batch technique was used taking metal ion in excess to the resin. Exchange capacities for Cd(II) and Hg(II) were determined in the pH range 1 to 6. The lower pH (i.e. 1-3) was adjusted with 0.1 M HCl and pH 4-6 was adjusted with 0.2 M sodium acetate buffer. To 50 mg of the chelating resin 30 mL of Cd(II) or Hg(II) solution (1000 µg mL-1) was added. The pH of the solution was adjusted at the desired value and equilibrated for 24 h. It was then filtered and washed with double distilled water to remove the unbound metal ions. The sorbed metal ions were then eluted with suitable eluants. Concentrations of Cd(II) was measured by FAAS, whereas that of Hg(II) was measured by CVAAS.

The resin containing adsorbed metal ions was shaken with 30 mL of different concentrations of 0.01-2 M HCl, 0.01-4 M HNO3 and thiourea (1-10%,
m/v) in 0.1-1 M HClO₄ and 0.1 M HCl. The amount of desorbed Cd(II) was determined by FAAS and Hg(II) by CVAAS.

A 130 mm×10 mm glass column was used for the present work. Air dried resin (1.5 g) was immersed in double distilled water and allowed to swell for 24 h. The column was then packed with the swollen beads and the bed volume was 2 mL.

The sorption and recovery characteristics for Cd(II) and Hg(II) in the presence of various other metal ions were thoroughly studied. A 100 mL portion of the mixture of the test metal ion was allowed to flow through the resin column at the flow rate of 0.5 mL min⁻¹. The sorbed Cd(II) and Hg(II) ions were completely eluted by (30 mL) 4 M HNO₃ and 10% thiourea in 1 M HClO₄, respectively.

Results and Discussion

Effect of microwave irradiation parameters on synthesis

Compared to classical method of prolonged refluxing, microwave-assisted synthesis is now a well-known time reducing technique. The effects of experimental parameters were determined using 500 mg of resin, 200 mg of Na₂CO₃ and 200 mg of 2-aminothiazole in 15 mL DMF in a closed PTFE reactor. The main objective was to obtain maximum amount of the desired resin by optimizing time and power. From Figs 1 and 2 it can be seen that the optimum conditions to obtain the desired product are 42 min and 300 W. The nitrogen content at higher power is decreased significantly, which may be due to the breaking of the ligand at higher pressure. The resin thus obtained was compared with the resin obtained by classical method (42 h refluxing) with respect to nitrogen content, IR spectra and metal ion capacities and it was found that both the products were identical.

Characterization of the resin

The resin was synthesized through the steps shown in Scheme 1. The nitrogen content of the resin was found to be 4.94%. Same result was obtained both from classically synthesized and microwave-assisted synthesized resin. The physical and chemical characteristics of the resin have been presented in Table 1.

![Fig. 1—Optimisation of time for microwave-assisted synthesis of the functionalized resin](image1)

![Fig. 2—Optimisation of power for microwave-assisted synthesis of the functionalized resin](image2)

![Scheme 1—Synthesis of the resin](image3)

**Table 1—Physical and chemical characteristics of the chelating resin**

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Color</td>
<td>Orange yellow</td>
</tr>
<tr>
<td>Bead size</td>
<td>200-400 mesh</td>
</tr>
<tr>
<td>Limit of thermal stability</td>
<td>310°C</td>
</tr>
<tr>
<td>Time (min) for 50% uptake of:</td>
<td></td>
</tr>
<tr>
<td>Cd(II)</td>
<td>10.8</td>
</tr>
<tr>
<td>Hg(II)</td>
<td>23.7</td>
</tr>
<tr>
<td>IR data</td>
<td>3450 cm⁻¹, 3355 cm⁻¹ and 1635 cm⁻¹ may be due to -NH stretch; 2346 cm⁻¹ for -SH; 1324 cm⁻¹, 1275 cm⁻¹, 1024 cm⁻¹, 694 cm⁻¹ and 274 cm⁻¹ for 2-aminothiazole moiety</td>
</tr>
<tr>
<td>Water regain (mmol/g)</td>
<td>7.63</td>
</tr>
</tbody>
</table>
The IR spectra of the final resin were compared with those of the chloromethylated resin and chelating ligand. It is to be noted that FTIR spectra of polymers are complicated. Therefore, only a few peaks could be assigned with reasonable certainty. The band at 668 cm\(^{-1}\) for -C-CI stretching had disappeared in the final resin. A few new bands appeared; e.g., those at 3450, 3355 and 1634 cm\(^{-1}\) may be due to -NH stretching. The band at 2346 cm\(^{-1}\) may be due to -SH stretching and 1324, 1275, 1024, 694 and 274 cm\(^{-1}\) due to 2-aminothiazole moiety. Same results were obtained for both classically synthesized and microwave-assisted synthesized resins.

The chemical stability of the resin was checked by treatment with 1-12 M H\(_3\)NO\(_3\), HCl and NaOH for 7 days. No significant change in nitrogen content was observed. Therefore, we may conclude that the resin is fairly stable in both acidic and alkaline medium. And for thermal stability, thermogravimetric analysis showed that the resin is stable up to 310°C.

The water regain capacity of the resin was assessed by the usual thermogravimetric analysis (Table 1).

**Exchange capacity of the resin**

Exchange capacity of a resin is dependent upon the total number of ion active groups per unit weight of material, and greater the number of ions, the greater will be the capacity. In case of 2-aminothiazole resin, if all the nitrogen were part of the chelating group then the exchange capacity of the resin should have been something like 1.76 mmol g\(^{-1}\). In fact, the resin shows a much lower exchange capacity. The low value may be due to the rigidity of the polymeric matrix and the inability of all the chelating groups to participate in chelation for steric restriction. By using batch technique, the maximum exchange capacity for Cd(II) and Hg(II) on 2-aminothiazole resin was found to be 0.15 and 0.51 mmol g\(^{-1}\), which is shown in Fig. 3.

**Sorption and desorption of metal ions**

By using batch technique, the sorption behaviour of Cd(II) and Hg(II) on 2-aminothiazole resin was determined. The effect of different eluants on the desorption of the metal ions is given in Table 2. Complete desorption of Cd(II) took place with 4 M HNO\(_3\) whereas for Hg(II) complete desorption took place with 10% thiourea in 1 M HClO\(_4\).

**Effect of diverse ions**

Separations of 2 \(\mu\)g mL\(^{-1}\) of Cd(II) and 2 ng mL\(^{-1}\) of Hg(II) in presence of macro amounts of diverse ions were carried out using column operation at pH 1 and 6, respectively (Table 3). Large excess of these foreign ions present in the binary mixtures during separation did not show any interference. Desorption of Cd(II) and Hg(II) was carried out with almost 100% recovery using suitable eluants as mentioned earlier. Hence attempts were made to separate Cd(II) and Hg(II) from binary mixtures and biological samples viz. mussel tissue, tomato leaves and rice flour.

**Equilibration rate**

The time required for 50% uptake of the maximum capacity for Cd(II) and Hg(II) was found to be 10.8 and 23.7 min respectively. This shows that the resin is suitable for column operation under a low flow rate (0.5 mL min\(^{-1}\)) condition.
Reusability of the resin

In order to test the ability for its reuse, the resin was subjected to several loading and elution cycles by batch as well as column method. It was found that the exchange capacity of the resin remained practically constant after its repeated use of more than 50 times. Thus, reuse of the resin column is feasible.

Analytical performance characteristics

Concentration range for the construction of calibration curve was linear up to 1 µg mL⁻¹ for Cd(II) and 10 ng mL⁻¹ for Hg(II) with regression coefficient (R²) values of 0.997 and 0.995 respectively. The quantification limits were evaluated as the concentration corresponding to 10 σ value of the blank signal and were found to be 5.70 and 0.14 ng mL⁻¹ for Cd(II) and Hg(II) by using synthetic sample solution blank.

The precision of the method was evaluated by five successive retention and elution cycles with 0.1 g of Cd(II) and Hg(II) in 100 mL of solution. It was observed that the recoveries were 99.58 ± 1.29 and 95.54 ± 2.71 for Cd(II) and Hg(II) respectively at 95% confidence level for both.

Applications

Mutual separation of Cd(II) and Hg(II) in binary synthetic mixtures

Different amounts of Cd(II) and Hg(II) solutions were mixed having a total volume of 50 mL and the mixture was subjected to column operation. Cd(II) was eluted first at pH 1 using 4 M HNO₃ followed by Hg(II) at pH 6 using 10% thiourea in 1 M HClO₄. The results are given in Table 4.

Separation and estimation of Cd(II) and Hg(II) in biological samples

The certified biological samples were digested in the microwave oven by the procedure described earlier. Then Cd(II) and Hg(II) were analyzed by FAAS and CVAAS respectively after separation through 2-aminothiazole resin. The results of the analysis are given in Table 5.

Conclusion

Microwave-assisted synthesis of the resin is a big time saver. This is clearly seen from the fact that where the classical method needs 42 h of refluxing it can be synthesized in only 42 min using microwave assistance. With respect to nitrogen content, IR spectra and metal ion capacities it was found that both the products, classically synthesized and microwave-assisted synthesized resins were identical.

<table>
<thead>
<tr>
<th>No. of observations</th>
<th>Amount taken (Cd in µg, Hg in ng)</th>
<th>Amount found</th>
<th>% Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Cd(II) 100</td>
<td>103.0±0.4</td>
<td>3.0</td>
</tr>
<tr>
<td></td>
<td>Hg(II) 100</td>
<td>95±0.1</td>
<td>5.0</td>
</tr>
<tr>
<td>2</td>
<td>Cd(II) 100</td>
<td>106.4±0.1</td>
<td>6.4</td>
</tr>
<tr>
<td></td>
<td>Hg(II) 50</td>
<td>48.2±0.3</td>
<td>3.6</td>
</tr>
<tr>
<td>3</td>
<td>Cd(II) 100</td>
<td>100.1±0.2</td>
<td>0.1</td>
</tr>
<tr>
<td></td>
<td>Hg(II) 10</td>
<td>9.2±0.1</td>
<td>8.0</td>
</tr>
<tr>
<td>4</td>
<td>Cd(II) 10</td>
<td>9.6±0.3</td>
<td>4.0</td>
</tr>
<tr>
<td></td>
<td>Hg(II) 100</td>
<td>97.6±0.3</td>
<td>2.4</td>
</tr>
<tr>
<td>5</td>
<td>Cd(II) 50</td>
<td>48.7±0.4</td>
<td>2.6</td>
</tr>
<tr>
<td></td>
<td>Hg(II) 100</td>
<td>106.1±0.1</td>
<td>6.1</td>
</tr>
</tbody>
</table>

Table 4—Mutual separation of Cd(II) and Hg(II) in synthetic binary mixtures in a sample volume of 50 mL.

Table 5—Separation and estimation of Cd(II) and Hg(II) in certified biological samples

<table>
<thead>
<tr>
<th>Biological samples</th>
<th>Certified value</th>
<th>Value obtained*</th>
<th>% Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mussel tissue</td>
<td>Cd : 1.32 µg g⁻¹</td>
<td>Cd : 1.37±0.3 µg g⁻¹</td>
<td>3.7</td>
</tr>
<tr>
<td></td>
<td>Hg : 950.0 ng g⁻¹</td>
<td>Hg : 990±0.2 ng g⁻¹</td>
<td>4.2</td>
</tr>
<tr>
<td>Rice flour (unpolished)</td>
<td>Cd : 1.82±0.06 µg g⁻¹</td>
<td>Cd : 1.87±0.1 µg g⁻¹</td>
<td>2.7</td>
</tr>
<tr>
<td>Tomato leaves</td>
<td>Cd : 3.0 µg g⁻¹</td>
<td>Cd : 3.1±0.3 µg g⁻¹</td>
<td>3.3</td>
</tr>
<tr>
<td></td>
<td>Hg : 100.0 ng g⁻¹</td>
<td>Hg : 94.0±2.1 ng g⁻¹</td>
<td>6.0</td>
</tr>
</tbody>
</table>

*Average of five determinations

<table>
<thead>
<tr>
<th>Foreign ion</th>
<th>% Recovery**</th>
<th>Cd(II)</th>
<th>Hg(II)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ag(II)</td>
<td>98.4±0.4</td>
<td>95.8±0.6</td>
<td></td>
</tr>
<tr>
<td>Pb(II)</td>
<td>94.3±0.3</td>
<td>106.7±0.3</td>
<td></td>
</tr>
<tr>
<td>Mn(II)</td>
<td>102.1±0.9</td>
<td>101.5±0.7</td>
<td></td>
</tr>
<tr>
<td>Fe(II)</td>
<td>99.2±1.1</td>
<td>97.6±0.8</td>
<td></td>
</tr>
<tr>
<td>Co(II)</td>
<td>106.3±1.4</td>
<td>100.1±1.1</td>
<td></td>
</tr>
<tr>
<td>Ni(II)</td>
<td>97.4±1.5</td>
<td>98.3±1.5</td>
<td></td>
</tr>
<tr>
<td>Cu(II)</td>
<td>97.3±0.4</td>
<td>96.5±1.5</td>
<td></td>
</tr>
<tr>
<td>Zn(II)</td>
<td>90.1±0.6</td>
<td>98.8±1.3</td>
<td></td>
</tr>
<tr>
<td>Na(I)</td>
<td>103.2±1.1</td>
<td>100.7±1.7</td>
<td></td>
</tr>
<tr>
<td>Mg(II)</td>
<td>98.3±1.3</td>
<td>99.0±1.1</td>
<td></td>
</tr>
</tbody>
</table>

*Foreign ions added were 2000 µg for cadmium and 2000 ng for mercury

**Average of five determinations
The results show that the resin containing 2-aminothiazole group is very selective for Cd(II) and Hg(II). This high selectivity may be due to soft basic sulphur atom, which plays a key role in binding, which may be followed by chelation via nitrogen atom. Thus, the resin has immense potential in preconcentration and removal of trace Cd(II) and Hg(II) from various matrices. The method is simple, rapid and very effective for the determination of cadmium and mercury.

Acknowledgements
One of the authors (S. Dutta) wishes to thank the University of Burdwan for providing the financial assistance in the form of JRF and Dr. B. C. Mondal for cooperation and helpful suggestions during the entire work.

References
Synthesis, Characterization, and Application of a New Chelating Resin Functionalized with Dithiooxamide

S. Dutta, A. K. Das

Department of Chemistry, The University of Burdwan, Burdwan 713104, India

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ABSTRACT: Chloromethylated polystyrene-divinylbenzene has been functionalized with dithiooxamide. The resulting chelating resin (DTOA) has been characterized by elemental analyses, infrared spectroscopy, thermogravimetric analysis, and metal ion sorption capacities. It has been used for the preconcentration and separation of Cu(II), Zn(II), Cd(II), and Pb(II) prior to their determination by FAAS. Parameters such as the amount of the resin, effect of pH, equilibration rate, sorption and desorption of metal ions, and effect of diverse ions have been studied. The maximum sorption capacities found are 0.97, 0.12, 0.08, and 0.12 mmol g⁻¹ for Cu(II), Zn(II), Cd(II), and Pb(II) at pH 6.0, 5.5, 1.0, and 5.5, respectively. The preconcentration factors are 100, 100, 50, and 50 for Cu(II), Zn(II), Cd(II), and Pb(II), respectively. Recoveries of the metal ions were 96 ± 5, 97 ± 6, 96 ± 5, and 96 ± 5 at 95% confidence level, whereas the limits of detection are 2.0, 1.3, 2.5, and 25.0 μg L⁻¹ for Cu(II), Zn(II), Cd(II), and Pb(II), respectively. The calibration curves were linear up to 12 μg mL⁻¹ (R² = 0.998), 20 μg mL⁻¹ (R² = 0.999), 2 μg mL⁻¹ (R² = 1.000), and 5 μg mL⁻¹ (R² = 0.979) for Cu(II), Zn(II), Cd(II), and Pb(II), respectively. The reliability of the method has been tested by analyzing certified samples. © 2006 Wiley Periodicals, Inc. J Appl Polym Sci 103: 2281-2285, 2007

Key words: solid phase extraction; chelating resin; Cu(II); Zn(II); Cd(II); Pb(II); FAAS determination; microwave-assisted digestion; certified samples

INTRODUCTION

Accurate analysis of metal ions especially at trace level is one of the most difficult and complicated analytical tasks. Solvent extraction and solid phase extraction are the two most common methods for the preconcentration and separation of trace elements from various matrices. Solvent extraction has some disadvantages due to the use of excess solvent, which not only makes the method costly but is also contrary to the idea of green chemistry. During the past two decades, the use of chelating resins for metal ion preconcentration and separation has been considerably increased.1-5 The basic advantages of most of the researches on chelating resin lie in the increased selectivity, high preconcentration factors, mechanical stability of the resin, reusability, and reproducibility. In fact, a good number of reports has been made from our groups.6-11 For the quantification of metals at low concentrations, it is necessary to use very sensitive instrumental techniques or preconcentration methods, to achieve detection limits within the range of the available equipment.12 Chelating resins are capable of preconcentrating metal ions selectively from a large aqueous volume and may be easily coupled with flame atomic absorption spectrometry (FAAS) detection to enhance its sensitivity.13-15

In the literature, many chelating resins are described that were synthesized using XAD,1,6-18,19,20 amberlite-IRC,21-23 chloromethylated PS-DVB2,3-7 as the copolymer backbone. Generally, chelating ligands bound to copolymers by covalent bonds are much more resistant to external effects than those immobilized by simple impregnation, but the resulting metal retention capacities are only at medium level. Accordingly, various chelating resins have been synthesized on the basis of Pearson’s hard and soft acids and bases (HSAB) approach and has been applied to various fields such as trace element analysis,7 waste water treatment, precious metal recovery,24 etc.

The combination of "soft" and "borderline" donor sites present in DTOA, bound to the copolymer by covalent linkage, is expected to result in a wider applicability and high exchange capacity. In this article, we report the synthesis of DTOA-functionalized chelating resin and its use in preconcentration and separation of Cu(II), Zn(II), Cd(II), and Pb(II) from aqueous solutions.

EXPERIMENTAL

Apparatus and reagents

A GBC Avanta atomic absorption spectrometer was used for absorbance measurement. The following conditions were used for determination of different metal