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Talanta 64 (2004) 981–988
Talanta
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Spectrophotometric determination of magnesium in pharmaceutical preparations by cost-effective sequential injection analysis

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Received 3 March 2004; received in revised form 20 April 2004; accepted 20 April 2004
Available online 20 July 2004

Abstract

A simple and rapid, inexpensive spectrophotometric method was proposed for magnesium assay in pharmaceutical preparations by sequential injection analysis (SIA). The method is based on the reaction between *o*-cresolphthalein complexone (CPC) and Mg(II) in alkaline media, yielding a pink colored complex with absorption maximum at 570 nm. Since the formation constant between Ca–CPC and Mg–CPC is similar, initially a sample/standard solution was aspirated into the holding coil followed by a mixture of masking-buffer solutions. This was done because masking of calcium should be accomplished before Mg–CPC complexation. Then the reagent was introduced into the reaction coil to produce a colored complex, which is measured spectrophotometrically at 570 nm. In this way the interference of calcium was reduced. Furthermore, all the parameters that affect the reaction were evaluated. The calibration curve is linear over a range of 0–20 mg l^{-1} of Mg(II) with a detection limit of 0.24 mg l^{-1}. A sample throughput of 80 samples per hour and relative standard deviation <2.0% were achieved. The proposed method was successfully applied for the assay of magnesium in three different compositions of pharmaceutical preparations (tablets). The results were found to be in good agreement with the manual flame atomic absorption spectrophotometry (FAAS) and UV-Vis spectrophotometry methods and with the claimed values by the manufactures. The *t*-test shows no significant difference at 95% confidence level.

Keywords: Spectrophotometric method; Magnesium; *O*-cresolphthalein complexone (CPC); Sequential injection

1. Introduction

Magnesium is an essential mineral for human nutrition mainly found in foods like cereals, nuts, cacao, meat, milk and vegetables. Magnesium has several important functions. It is involved in energy metabolism, acting as a metal activator or co-factor for enzymes requiring adenosine triphosphate (ATP), in replication of DNA and in the synthesis of RNA and proteins; it appears to be essential for all phosphate transferring systems. Together with calcium, magnesium is involved in muscle contraction and blood clotting [1,2]. Its deficiency occurs, in general as complications of other diseases like alcoholism, diabetes, and kidney failure and in some post-operative periods. Magnesium deficiency can be treated by oral or parental administration of some magnesium salts (magnesium supplement tablets). Over supply in severe cases lead to coma and death [2]. Therefore, pharmaceutical preparations (tablets) that contain magnesium in their composition need validated methods of analysis for determining magnesium with simple, low operational costs, reliability and a high throughput.

With the choice depending on the precision and sensitivity required, a great variety of methods can be used for magnesium analysis in different sample matrices. A validated titrimetric method for the determination of magnesium in drugs including multi-vitamins with minerals can be found in the Official Method of Analysis of AOAC International [3]. Other instrumental methods, which are used, for magnesium analysis in various samples (matrices) include ion chromatography with a piezoelectric detector [4], inductively coupled plasma atomic emission spectrometry [5], inductively coupled plasma mass spectrometry [6], flame atomic absorption spectrometry [2,7], atomic absorption spectrometry [8], ion selective electrode [9] and

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doi:10.1016/j.talanta.2004.04.026

UV-Vis spectrophotometry [10]. Some of these methods are expensive and non-portable analytical equipment [4–8] and cannot be used sufficiently for routine analysis in small local drug laboratories.

UV-Vis spectrophotometry is the most convenient technique because it is simple, rapid and inexpensive and can be used for the determination of elements in a variety of samples. Manual spectrophotometric analysis is prone to operator's error. Automating the analysis reduces operator input and analysis time. Flow analysis methods are generally techniques that allow reactions to be fully automated. At present, flow injection analysis (FIA) and sequential injection analysis (SIA) are the most used methods in flow analysis, with preference for SIA application due to its economical sample and reagent consumption with minimum waste generation. For this reason a SIA system with UV-Vis spectrophotometric detection has been proposed for magnesium analysis in different compositions of pharmaceutical preparations.

Other methods used for magnesium analysis based on flow based procedures in different sample matrices include continuous on-line feedback based flow titration [11], FIA based on magnesium ion-selective electrode [12], SIA with spectrophotometric [13] and flame atomic absorption spectrophotometric [14] detectors. Hernandez et al. [15] employed multi-component flow injection based analysis with diode array detection and least square multivariate calibration evaluation for determination of calcium and magnesium in waters and dialysis liquids. Recently, Rocha et al. [16] developed a multi-commutation-based flow system for multi-element analysis in pharmaceutical preparations.

As compared to flow-based procedures mentioned above, SIA systems are versatile and efficient for automating the steps required for an analytical procedure. The versatility of the system is centered around the selection valve where each port of the valve allows different operations to be performed [17]. In a typical system, the valve selects the sample and reagent volumes to be sequentially aspirated towards the holding coil where homogenization occurs; the flow is then reversed and the valve is switched in order to direct the processed sample towards the detector.

Due to stricter law enforcement local pharmaceutical companies are now required to carry out content uniformity tests on larger sets of individual tablets on a daily basis. This resulted in a higher sample throughput with a pre-requisite on shorter analysis time. There is further, a very strong movement in southern African countries to keep the cost of final pharmaceutical products as low as possible resulting on economic restraints in the production line. The further need to improve sample handling and to produce accurate and reproducible results at the same time with low cost instrumentation in a clean environment enhance the replacement of sophisticated [4–8] instrumentation with systems that are easy to operate, are simple, rapid, easy to automate and are reliable. SIA with inherent advantages such as low sample and reagent consumption with UV-Vis spectrophotometric detection (preferred in local pharmaceutical companies above FAAS as detector due to low cost and cleaner environment) forms an ideal tool for magnesium analysis in local pharmaceutical companies.

Considering the favorable characteristics of the SIA systems, it is natural to use them for in-line masking of the interfering species in the sample and determine the analyte sought. In this analysis, a sample/standard, a mixture of masking-buffer, and reagent solutions are modified (nested) around the selection valve, thereafter each solution was aspirated sequentially into the holding coil and with flow reversal channeled to the detection so that masking of calcium could take place in-line in the flow conduit before Mg–CPC complexation takes place. In this way the interference of calcium and some other ions were reduced in magnesium analysis. All analytical parameters of the system were thoroughly studied and optimized. The method optimized is found to be selective and sensitive and successfully applied for magnesium analysis in three different compositions of tablets.

2. Experimental

All reagents used, were of analytical reagent grade and all solutions were prepared with de-ionized water. De-ionized water was obtained from a Modulab system (Continental Water System, San Antorio, TX, USA).

Samples: Vita force 21-Plus (sample 1) supplied by Pharma Natura (Pty) Ltd., South Africa; magnesium with B6 (sample 2) supplied by The MY Vitamin Company (Pty) Ltd., South Africa and Bettaway Dolomite a combination of calcium and magnesium (sample 3) supplied by Better Nutrition (Pty) Ltd., South Africa.

2.1. Reagents and standard solutions

A stock standard magnesium solution containing 1000 mg/l Mg(II) was prepared by dissolving 5.135 g of magnesium sulfate ($MgSO_4 \cdot 7H_2O$) (Merck) with de-ionized water in a 500 ml volumetric flask and diluted quantitatively to the mark with de-ionized water. Working standard solutions were prepared by appropriate dilution of the stock solution with de-ionized water. A stock solution of 0.03% (w/v) *o*-cresolphthalein complexone (CPC) was prepared by dissolving 0.075 g of CPC with 3 ml of 5 mol l^{-1} HCl in a 250 ml of volumetric flask and then diluted with de-ionized water to the mark. Appropriate working solutions were prepared by diluting the stock solution with de-ionized water. A mixture of masking agent and ammonia/ammonium hydroxide buffer solutions were prepared by dissolving 13.4 g ammonium chloride (NH_4Cl, Merck), 10 g of sodium hydroxide (NaOH), 0.195 g of barium chloride ($BaCl_2 \cdot 2H_2O$, Merck), 0.285 g of EGTA (BDH) and 5 g of potassium cyanide (Merck) in 400 ml of de-ionized water, the pH adjusted to 10.5 with 5 mol l^{-1} HCl and diluted to 500 ml with

de-ionized water. De-ionized water was used as a carrier stream.

2.2. Sample preparation

Three tablets of each sample (Vita force 21-Plus; magnesium with B6 and Bettaway Dolomite, purchased from local shops) were placed individually in a conical volumetric flask and dissolved with 15 ml of 2 mol l^{-1} hydrochloric acid and boiled gently for few minutes. Then the solution was cooled, diluted with de-ionized water to 50 ml and centrifuged to separate the residue from the supernatant. The residue was again washed twice with de-ionized water, centrifuged and added to the supernatant. The pH of the supernatant was adjusted to pH 6 with 0.2 mol l^{-1} NaOH solutions, transferred into a 1 l volumetric flask and diluted to the mark. Further dilution (Vita force 21-Plus was diluted to two-fold, magnesium with B6 and Bettaway Dolomite tablets were diluted to four-fold) was made with de-ionized water for the appropriate concentration.

2.3. Apparatus

A single wavelength Unicam 5625 UV-Vis spectrophotometer (Cambridge, UK) equipped with a 10 mm Hellma-type flow through cell (Hellma GmbH and Co., Mulheim/Baden, Germany) was used in all SIA experiments. A 10 position micro-actuated selection valve (E-10-230, Valco instruments, Houston, TX, USA) and a Gilson Minipuls-3 peristaltic pump (M321, Gilson, Villiers-le-Bel, France) were also used in the SIA system. For the device control and data acquisition, a FlowTEK interface box and FlowTEK software package (obtained from MINTEK Randburg, South Africa) for computer aided flow analysis were used throughout the experiment. The manifold SIA system is given in Fig. 1.

Table 1
Device sequence used for one cycle of the SIA system for magnesium analysis in pharmaceutical preparations

Time (s)	Pump	Valve	Description
0	Off	Sample	Pump off, valve select sample stream
2	Reverse		Draw up the sample solution
3.5	Off		Pump stop
4.5		Masking-buffer	Select masking-buffer solution (valve position 2)
5.5	Reverse		Draw up masking-buffer solution
6.5	Off		Pump stop
7.5		Reagent	Select reagent solution (valve position 3)
8.5	Reverse		Draw up reagent solution
10.0	Off		Pump stop
11.0		Detector	Select the detector stream
12.0	Forward		Pump the stack of zones toward the detector
43	Off		Pump stop
45	Home		Complete one cycle and valve return back to position 1

2.4. Procedure

An illustration of the device sequence for magnesium analysis in pharmaceuticals preparations is shown in Table 1. A sample solution, a mixture of masking-buffer solution and a reagent solution were aspirated sequentially through the selection valve into the holding coil. By flow reversal the stack of well-defined zones were propelled by the peristaltic pump from the holding coil to the reaction coil. The zones penetrate each other as they pass through the reaction coil

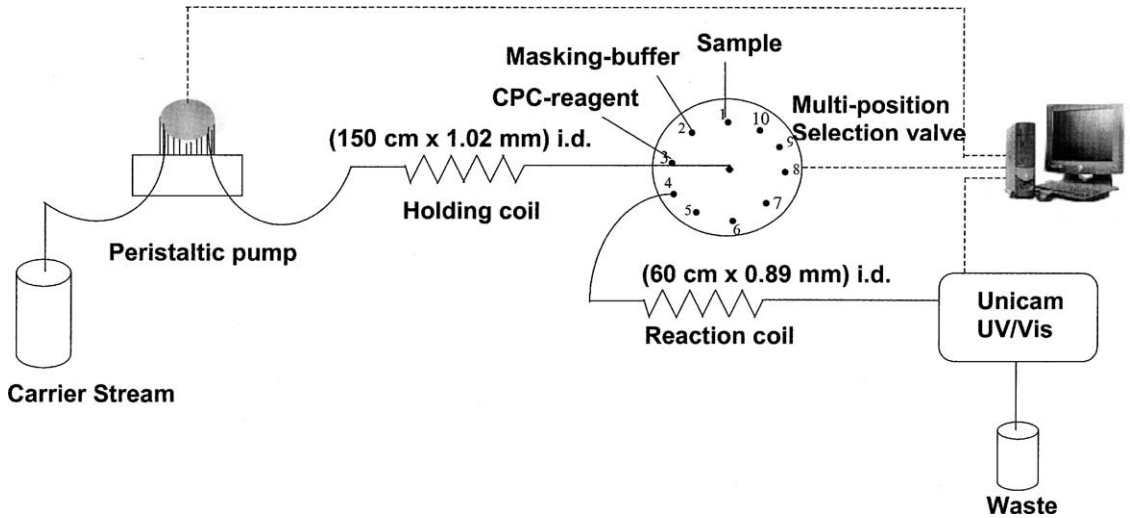

Fig. 1. Schematic representation of the proposed SIA manifold used for magnesium analysis.

to the detector. The absorbance of the complex is measured at 570 nm using an UV-Vis spectrophotometer.

3. Results and discussion

As the formation constants of the Ca–CPC and Mg–CPC complexes are similar ($K = 2.5 \times 10^6$ and 3.2×10^7 for calcium and magnesium, respectively [16]), a careful selection of the masking agent and order of aspiration into the system was necessary. In this work, Ba-EGTA masking agent was used to eliminate the interference of calcium. In order to minimize calcium interference, initially a sample/standard was aspirated into the holding coil followed by a mixture of masking-buffer solution. Thereafter, a CPC reagent was aspirated towards the holding coil to produce a colored Mg–CPC complex, which is measured spectrophotometrically. This was done because calcium masking should be accomplished before the Mg–CPC complexation. The influence of the pH of the mixture of masking-buffer solution and concentration of the CPC reagent were studied and optimized. Furthermore, the influence of various operational parameters of SIA system on the formation of Mg–CPC complex was investigated and optimized for magnesium analysis in pharmaceutical preparations as described below. In all cases both the mean relative peak height (for $n = 10$ repetitive determinations) and the relative standard deviation were used as a criteria for establishing the most appropriate parameter. The optimum condition, which was used for magnesium analysis, is given in Table 2.

3.1. Method optimization

3.1.1. Flow rate

The influence of the flow rate on sensitivity and precision was investigated between 2.5 and 7.5 ml min^{-1} with steps of 0.625 ml min^{-1} flow rate while keeping the volume of solutions constant by changing aspiration time accordingly (Fig. 2). It was observed that there is an increase in sensitivity with an increase in the flow rate upto 5.1 ml min^{-1} and then a decrease for higher flow rates. Thus, a flow rate of 5.1 ml min^{-1} was selected due to highest sensitivity and precision and used for subsequent measurements.

Table 2
Optimum working conditions

Parameter	Value
Flow rate	5.1 ml min^{-1}
Holding coil	
Diameter i.d.	1.02 mm
Length	150 cm
Configuration	Coiled
Reaction coil	
Diameter i.d.	0.89 mm
Length	60 cm
Configuration	Coiled
Sample volume	126 μl
Reagent volume	85 μl
Masking-buffer solution	126 μl
Concentration of ammonia/ammonium hydroxide	0.50 mol l^{-1}
Concentration of *o*-cresolphthalein complexone	1.8×10^{-2}% (w/v)
pH of ammonia/ammonium hydroxide	10.5
Wavelength	570 nm

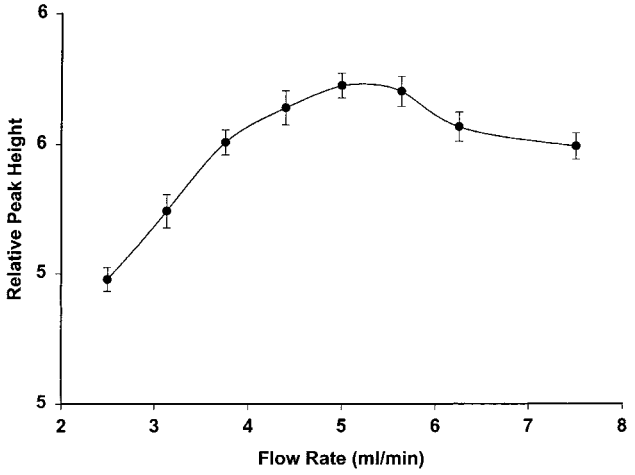

Fig. 2. Influence of flow rate on sensitivity and precision. Experimental conditions were: reaction coil = 0.76 mm i.d. × 80 cm, holding coil = 1.02 mm i.d. × 200 cm, aspiration of sample, masking-buffer, and reagent volumes = 147, 85 and 126 μl, respectively, pH of the masking-buffer = 10.5, CPC = 0.02% (w/v) and sample concentration = 40 mg l^{-1} Mg(II).

3.1.2. Holding coil length and diameter

The main function of this tubing is to serve as a holding reservoir of sample reagents that is sequentially aspirated into it and should be large enough to prevent the stack of zones from entering the pump conduit [18]. As the stack of zones are forwarded from the holding coil towards the reaction coil, a certain degree of zone penetrations take place depending on the line length and dimensions of the coil. In order to obtain the best reaction conditions in terms of degree of zone penetration (sensitivity) and precision, various line lengths and inner diameters were studied for the holding coil.

Line length: the line length of the holding coil was evaluated between 150 and 200 cm with increasing steps of 25 cm. As expected no significant difference in sensitivity was obtained with increasing line length, but it did show differences in precision. A line length of 150 cm for the holding coil was chosen due to its precision.

Tube inner diameter: three different tube diameters (0.89, 1.02 and 1.14 mm) on sensitivity and precision were tested. A slight decrease in sensitivity with increasing coil diameter was obtained. A coil diameter of 1.02 mm was chosen due to highest precision and used for subsequent measurements.

3.1.3. Reaction coil length and diameter

As the stack of sample and reagents solutions are propelled through the reaction coil on the way to the detector,

they penetrate each other and a product zone is formed which is recorded as a peak by detector. Depending on the dimension and the line length of the reaction coil, the product zone will undergo physical dispersion as it is transported all the way to the detector. In order to avoid excessive dilution (dispersion) of the formed product zone, the reaction coil is usually kept as short as possible [18].

Line length: the line length of the reaction coil was evaluated between 60 and 100 cm with increasing steps of 20 cm. The sensitivity slightly decreases with an increase in the line length of the reaction coil confirming the rapidness of the reaction. Thus, a line length of 60 cm for the reaction coil was selected due to its sensitivity.

Tube inner diameter: various diameters of the reaction coil (0.64, 0.76, 0.89, 102 and 1.14 mm) were tested. It was observed that the sensitivity first increased slightly with an increase in the inner coil diameter upto 0.89 mm and then slightly decreased. A 0.89 mm was chosen due to the highest sensitivity and precision obtained.

3.1.4. Reagent concentration

By varying the concentration between 3.0×10^{-3} and 1.8×10^{-2}% (w/v), the effect of CPC concentration on sensitivity and precision was tested and the results are shown in Fig. 3. The results show that increasing the CPC concentration increases the sensitivity upto 1.5×10^{-2}% (w/v), above which the slope flattened-off and remained virtually constant. Thus 1.5×10^{-2}% (w/v) CPC was selected.

3.1.5. pH of mixture of masking-buffer solutions

The effect of the pH of this solution was investigated between 8.5 and 11 at a constant concentration of the solutions (Fig. 4). The results show that there is a sharp increase in sensitivity upto a pH of 10.5, above which the slope flattened-off and remained almost constant. A pH of 10.5 was selected for further work due to precision.

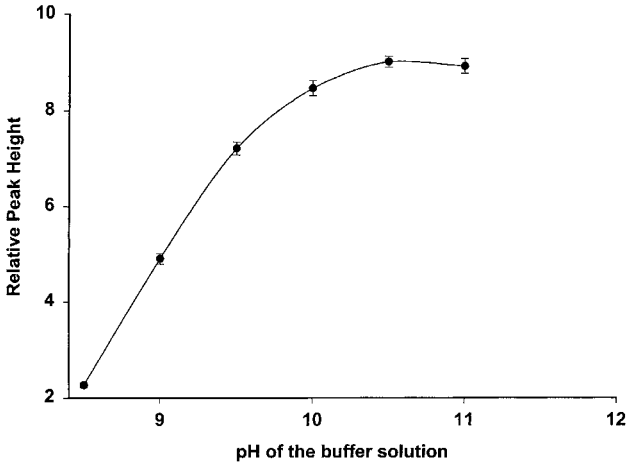

Fig. 4. Influence of the pH of a mixture of masking-buffer solution on sensitivity and precision. Experimental conditions were: reaction coil = 0.89 mm i.d. × 60 cm, holding coil = 1.02 mm i.d. × 150 cm, aspiration of sample, masking-buffer, and reagent volumes = 147, 85 and 126 μl, respectively, CPC concentration = 0.018% (w/v), flow rate = 5.1 ml min^{-1} and sample concentration = 40 mg l^{-1} Mg(II).

3.1.6. Sample, reagent and buffer volumes optimization

The aim of optimization of these parameters is to minimize the consumption of reagent volumes while maintaining the best sensitivity and reproducibility of the method for the analyte to be determined. The method adopted for optimizing these parameters was to keep the volumes of the two solutions constant while varying the other one at different

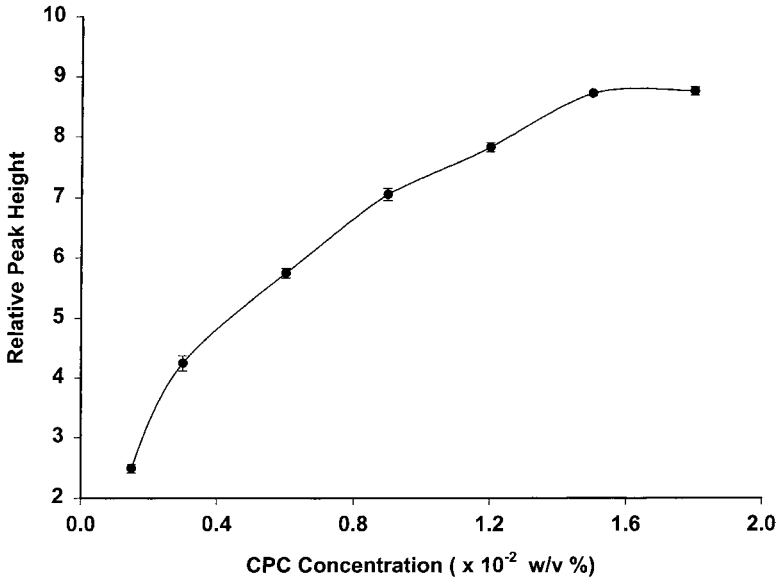

Fig. 3. Influence of CPC concentration on sensitivity and precision. Experimental conditions were: reaction coil = 0.89 mm i.d. × 60 cm, holding coil = 1.02 mm i.d × 150 cm, aspiration of sample, masking-buffer, and reagent volumes = 147, 85 and 126 μl, respectively, pH of the masking-buffer = 10.5, flow rate = 5.1 ml min^{-1} and sample concentration = 40 mg l^{-1} Mg(II).

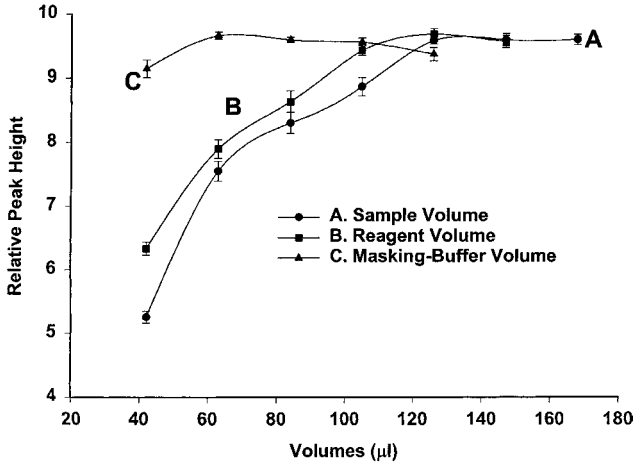

Fig. 5. Influence of sample (A), reagent (B) and masking-buffer (C) volumes on sensitivity and precision. Experimental conditions were: reaction coil = 0.89 mm i.d. × 60 cm, holding coil = 1.02 mm i.d. × 150 cm, CPC concentration = 0.018% (w/v) and flow rate = 5.1 ml min^{-1}, aspiration of (A) masking-buffer volume = 85 μl and reagent volume = 126 μl, (B) sample volume = 126 μl and masking-buffer volume = 85 μl, (C) sample volume = 126 μl and reagent volume = 126 μl and sample concentration = 40 mg l^{-1} Mg(II).

volumes. This procedure was repeated for each volume as described below.

It is important to optimize sample volume to ensure that effective mixing of the sample with the reagent and masking-buffer solution was obtained. The effect of this volume was investigated between 43 and 168 μl with increasing steps of 21 μl while keeping the two solutions (reagent and masking-buffer) and flow rate constant. As can be seen in Fig. 5(A), the sensitivity increases with an increase in sample volume upto a volume of 126 μl, above which the slope flattened-off and remained virtually constant. A sample volume of 126 μl was selected for subsequent measurements.

The effect of reagent (CPC) volume on sensitivity and precision was studied between 43 and 147 μl with increasing steps of 21 μl and constant sample and masking-buffer volumes (Fig. 5(B). There is a sharp increase in sensitivity upto a volume of 105 μl, above which the slope flattened-off. A reagent volume of 126 μl was selected due to precision for further work.

The first pre-requisite was that a certain amount of ammonia/ammonium hydroxide buffer solution was necessary in the stack of zones to produce an optimal buffer capacity at a pH of 10.5. The effect of the mixture of masking-buffer volume was evaluated between 43 and 126 μl with increasing steps of 21 μl and constant volumes of the two solutions (Fig. 5(C). There is a slight increase in sensitivity upto a volume of 85 μl whereafter, the slope flattened-off and remained constant. A volume of 85 μl was selected due to its sensitivity and precision and used for subsequent measurements.

4. Method evaluation

The proposed sequential injection system was evaluated under the optimum conditions (Table 2) with regard to response linearity, accuracy, precision sample carryover, sampling frequency and interference.

4.1. Linearity, detection limit, accuracy, sample carry over and precision

The linearity of the current method for magnesium analysis was evaluated under the optimum conditions. The relationship obtained between the mean relative peak height and Mg(II) concentration is given by the equation

$$\text{mean relative peak height} = 0.2808\,[\text{Mg(II)}] + 0.077,$$
$$R^2 = 0.996$$

The linear concentration range is between 0 and 20 mg l^{-1} of Mg(II).

The detection limit gives an indication of the lowest concentration of magnesium(II) that can be distinguished from the background signal with 99% certainty. The detection limit was calculated as follows:

$$\text{DL} = \frac{(3\delta + k)(k - b)}{m}$$

where k is the relative peak height of the background, δ the standard deviation of the background, b the intercept of the calibration graph and m the slope of the graph. The calculated detection limit was 0.24 mg l^{-1} of Mg(II).

In order to estimate the accuracy of the proposed method three real samples (three tablets of different compositions) were analyzed for magnesium contents and the results are shown in Table 3. The results obtained by the proposed SIA system are consistent (in good agreement) with the manual FAAS, manual UV-Vis spectrophotometric method and claimed values by the manufacturers. Thus, we can conclude that the proposed SIA system is valid for magnesium

Table 3
Comparison of the results (as mg/tablet) obtained for Mg(II) from real samples

Samples	Proposed SIA system	Manual FAAS method	Manual UV-Vis spectrophotometry	Claimed values
Vita force 21-Plus	24.76 ± 2.13	25.83 ± 1.07	24.97 ± 0.12	25.50
Magnesium with B6	37.24 ± 1.13	37.90 ± 1.65	37.83 ± 0.18	37.50
Bettaway Dolomite	47.64 ± 0.79	48.0 ± 2.01	48.30 ± 0.10	48.0

All values are averages from three determinations.

analysis in different compositions of pharmaceutical preparations under the optimum conditions described above.

Sample interaction/carryover effect between consecutive samples was investigated by analyzing a sample with lower analyte concentration followed by that of higher concentration and again with the lower concentration. A sample containing 2 mg l^{-1} Mg(II) was used for the lower concentration and 20 mg l^{-1} Mg(II) was used for the higher analyte concentration. The carryover was then calculated as follows:

$$\text{carryover} = \frac{H_3 - H_1}{H_2} \times 100$$

where H_1 is the mean relative peak height of the analyte containing 2 mg l^{-1} Mg(II), followed by H_2 the mean relative peak height of the analyte containing 20 mg l^{-1}, followed by H_3 the mean relative peak height of the analyte containing 2 mg l^{-1} Mg(II). The calculated carryover effect was found to be 0.93%, which is negligible.

The precision of the method was evaluated by 10 repetitive determinations of the standard solutions and the RSD for the linear range from 0 to 20 mg l^{-1} Mg(II) was found to be between 0.70 and 1.9%.

4.2. Sampling frequency

The experimental period for one complete analytical cycle was 45 s long and this gave an over all sampling rate of 80 samples per hour.

4.3. Interferences

The influences of foreign ions, which are present in the tablets, were tested as possible interferences for the proposed method. The study was conducted by analyzing a standard solution of magnesium (5 mg l^{-1} Mg(II)) to which increasing amounts of interfering species (foreign ions) were added. The tolerance limit was defined as the concentration of added ions causing less than 3% relative error of the average absorbance for 10 repetitive measurements for the standard magnesium solution with no interference. It was found that Fe(II), Zn(II), Mn(II), Cu(II), and Ca(II) did not interfere with magnesium analysis upto 100 mg l^{-1} (maximum concentration tested and this was much higher than the amount of these species found in the tablets). Thus, we can conclude that the method is highly selective and sensitive for magnesium analysis in pharmaceutical preparations and other matrices under the optimum conditions described above.

5. Statistical comparison

A comparison was made between the proposed SIA system and a manual UV-Vis spectrophotometric method as well as between the proposed SIA system and a manual FAAS method and the results are given in Table 3. This comparison was made to establish, whether the SIA system gives reliable results and be accepted for magnesium(II) analysis in pharmaceutical preparations. Null-hypothesis testing and a *t*-test with multiple sample mean (paired by difference) were applied to examine, whether the three methods differ significantly at 95% confidence level. The *t*-calculated values for samples 1, 2 and 3 are 0.17, 0.89 and 1.43, respectively for the manual UV-Vis spectrophotometric method and 0.78, 0.57 and 0.29, respectively for the manual FAAS method. The tabulated critical value of *t* at 95% confidence level and four degree of freedom is 2.78 [19]. Since the calculated *t*-values are much less than the tabulated critical value, the null-hypothesis (H_0) cannot be rejected which indicates that there is no significant difference between the proposed and manual methods for magnesium(II) analysis in the pharmaceutical preparations.

6. Conclusions

The proposed SIA system for magnesium analysis is simple, inexpensive, reliable and readily available, rapid and more economical in terms of sample and reagent consumption with minimum waste generation. The interference of calcium and zinc were greatly reduced by the use of mixture of potassium cyanide and Ba-EGTA masking agent [20] and the correct order of sequential aspiration of the solutions into the system. The system presented a high sample frequency, which makes it suitable for routine analysis. The system is fully computerized and is able to monitor magnesium concentration at a frequency of 80 samples per hour with a relative standard deviation <2.0%. The calibration graph is linear between 0 and 20 mg l^{-1} of Mg(II) with a detection limit of 0.24 mg l^{-1}. The method is successfully applied for magnesium analysis in three different compositions of pharmaceutical preparations and shows no significant difference with the manual methods and claimed values by the manufacturers at 95% confidence level.

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