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Determination of magnesium by the solution scanometric method in a coloured titan yellow magnesium hydroxide complex form

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Abstract

In this work, the magnesium content was determined by the solution scanometric method using titan yellow (TY) as a complexing agent in alkaline media. This method is based on scanning a solution containing the pink-coloured product of the combination of TY and the magnesium hydroxide complex. Hydroxylamine hydrochloride (HA) and starch were utilised as colour stabilizers and protective colloids, respectively. After the cells containing the sample solution were scanned, the colour of each cell was analysed with software written in Visual Basic (VB 6) in terms of the red, green and blue values. The parameters used for optimisation include the reaction time and the concentration of TY, sodium hydroxide, starch and HA. The system had a wide linear range between 0.070 and 30.000 $\mu g\,mL^{-1}$ concentrations of magnesium, with a detection limit of 0.058 $\mu g\,mL^{-1}$ and a relative standard deviation of 1.90% for the G colour value. In addition, the effects of some foreign species were investigated. The method was successfully applied for the determination of magnesium in almond gum and three water samples.

Keywords: Magnesium; Solution scanometry; Titan yellow; Plexiglas® cell

1. Introduction

Magnesium is the eighth most abundant element in the crust of the Earth. The determination of alkaline earth metals, particularly magnesium, is of importance for environmental, biological and industrial applications [1]. Magnesium, an abundant mineral in the body, is naturally present in numerous foods, added to other food products, available as a dietary supplement, and present in some medicines (such as antiacids and laxatives). It is also a cofactor in more than 300 enzyme systems that regulate diverse biochemical reactions in the body [2–4].

Several reagents for the determination of magnesium have been described in the literature, such as eriochrome black T [5], titan yellow (TY) [6,7], ammonium phosphate method [8], EDTA [9], paratolyl-2-thenohydroxamic acid and quinalizarin [10], 4 methyl-3-((1-H-Indol-3-iyl) (phenyl) methyl)-1-H-Indol (MPBIM) [11] and trizma-chloranilate [12].

TY, also known as thiazole yellow, titangelb, clayton yellow and direct yellow 9, is a triazene dye that is used in display devices [13], optical sensors [14], lithographic processes [15], inks [16], paints [17], and incandescent

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electric lamps [18] as well as an albumin detector [19], fluorescent indicator in microscopy, and acid–base indicator [20]. It is also used as an important reagent for the detection of magnesium [7,21].

With the large contribution of Kolthoff [21] in 1926, TY was introduced in 1926 as an outstanding reagent for the determination of Mg^{2+} ions, after which the detection method was further developed through the co-operation of Lehr and Wesemeale (1950) [7]. Among all of the techniques for this determination, the procedure of Neil [6] in 1965 was of great importance and was preferred to other methods because it provides a higher ratio of colour intensity/blank.

The solution scanometric technique was introduced recently by Abbaspour et al. [22]. They used commercially available flatbed-scanners to obtain images of coloured solutions. The obtained images were transferred to a computer for an analysis and measurement of the intensity of the solution colour. The method is based on the reaction in solution phase in Plexiglas® cells. The solution was scanned, and the red, green and blue (RGB) colour model was used to analyse the solution color [23–25]. Afterwards, this method was coupled with cloud point extraction as a detection system in our group [26].

Scanometry has several advantages, such as simplicity (handheld scanner and PC), high scanning speed, inexpensive, portability, easy immobilisation of reactants, lack of a requirement of identifying λ_{max}, large archive of experiences, short response time, limited interference, ability to run various tests simultaneously and ability to investigate non-transparent samples by analysing the reflective properties of the surface.

In the present work, solution scanometry, as a simple, fast, and costs effective method, was developed to determine the Mg^{2+} ion content based on the formation of a pink coloured complex between Mg^{2+} ions and TY in sodium hydroxide medium and in the presence of starch as a colloidal protector and in the presence of HA as a colour stabilizer.

2. Experimental

2.1. Apparatus

The cells (with 1000 μL volume each) were built by using a sheet of Plexiglas® [22]. A Canoscan LiDE 200 flatbed scanner was used to scan the Plexiglas® sheet. The horizontal and vertical resolution of the scanner was set to 300 dpi. Furthermore, the colour of each cell was analysed with respect to the red, green and blue values using software written in Visual Basic 6 (VB 6) for [27,28]. Three Biohit proline pipettors with different volumes between 0.5 and 1000 μL were used for injecting samples into the cells.

2.2. Chemicals and reagents

All of the chemicals used in this work were of analytical grade. In addition, double distilled water was used throughout. TY was purchased from Merck (E. Merck, Darmstadt, Germany). A laboratory stock solution (0.02%, w/v) was prepared by dissolving crystalline TY in double distilled water. The analytical-grade magnesium nitrate, sodium hydroxide, starch and hydroxylamine hydrochloride used in this study were obtained from Merck.

2.3. Principles of the red, green and blue (RGB) colour systems

The RGB colour system works on the basic principle that any colour is composed of red, green and blue. Colours are created by adding more light to a starting colour of black, and for this reason, it is also known as the additive colour system. Every colour in the RGB spectrum is made up of a different value for each of its red, green and blue components. Hence, it is used by systems that have the ability to add light, such as LCD, CRT and RGB projectors. RGB colours vary between 0 and 255, a range that a single 8-bit byte can offer by encoding 256 distinct values. In the RGB system, any colour is represented in the form of (R, G, B), in which the (0, 0, 0) and (255, 255, 255) refer to black and white, respectively. Therefore, by increasing the intensity of colours, the colour values are decreased. In this system 16,777,216 colours can be made. Any colour can be described by the following formula:

$$V = \mathrm{R} + 256\mathrm{G} + 256^2\mathrm{B}$$

where R, G and B are red, green and blue values of the main colour, respectively. For black and white, V is equal to 0 and 16,777,216, respectively. By using the following flowchart, R, G and B values of V for any colour can be extracted:

$$\mathrm{R} = V \,\mathrm{Mod}\, 256$$

$$\mathrm{G} = \frac{(V - R)\mathrm{Mod}(256^2)}{256}$$

$$\mathrm{B} = \frac{V - \mathrm{R} - \mathrm{G} \times 256}{256^2}$$