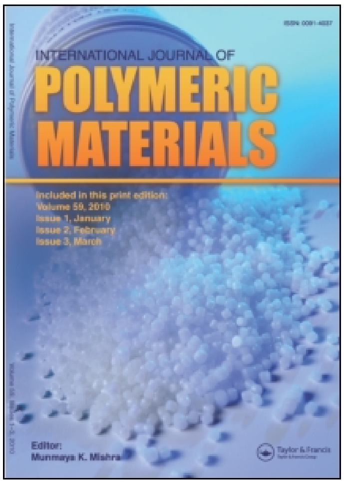

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Graphic Manifestation of the Ability of Selected Alkaline Earth Chlorides to Impart Flame-Retardancy to Cotton Fabric

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Optimum percent quanties of selected alkaline earth chlorides used for imparting flame-retardancy to cotton fabric have been chosen from one of the author's ACS-presented articles. Based on the afore mentioned data and gathering information concerning their physicochemical specifications from scientific literature the related graphical representations were obtained. The results illustrate a reasonable dependence in lowering the ability of the alkaline earth chlorides on their higher stabilities that is, the optimum percent of the applied chlorides decreased according to the metals position in the periodic table. Therefore a better understanding has been achieved and deduced.

Keywords: alkaline earth chlorides, flame-retardancy, flammability

INTRODUCTION

The flame-retardation of cellulosic materials has been extensively evaluated over the last sixty years with much work on the role of the inorganic salts being reported in the literature and in classical reference texts. These applications to fabric are mostly fulfilled by impregnation with an aqueous solution possessing the suitable concentration range, by means of squeeze rolls, followed by oven drying.

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By using one of the flammability tests the fabric's combustibility could be estimated and the comparison with untreated fabric could also be accomplished. So that the deduction about minimum add-ons percent of the material incorporated to the fabric for the impartation of flame-retardancy may be achieved. The corresponding author has investigated the effectiveness of different inorganic compounds to be applied as flame-retardants into cotton fabric, and so on. The results have been published in several articles in recent years [1–9], including this journal [10]. Among these articles, the article-entitled: "Effect of Selected Inorganic Chlorides on The Flame-Ratardancy Imparted to Cotton Fabric," written under supervision of the Late professor F. M. Farhan was presented at the 198th ACS National Meeting in Miami Beach Florida on September 1989. This article was also fully published in the *International Journal of Chemistry* [2].

The intention of the present study is to investigate the relationship between the efficient percent of certain alkaline earth chlorides to impart flame-retardancy to cotton fabric with some of their physicochemical characteristics obtained from scientific literature [11–15].

lt is mentionable that the experiments with beryllium and radium chlorides were abandoned due to the toxicity of beryllium dust, that is, in contact with the skin it causes dermatitis, and inhaling its dust or smoke causes a disease called berylliosis, which is rather like silicosis [12]. The application of radium chloride has not been accomplished because of the scarcity and radioactivity of radium compounds.

EXPERIMENTAL

All materials and the procedures have been described in the previous published articles [2–10]. However, a detailed description of the flammability test is given as follows:

Flammability Test

A vertical test method for the estimation of the fabric's combustibility has been originated and named as Mostashari's Flammability Tester (Figure 1). It is a rectangular aluminum frame cut on from one of its smaller sides. It has internal splits for inserting the fabric. The frame has also five sets of holes in each of its parallel legs so that pining of the fabric has been possible inside it. A frame with the following specification has been applied: Two strips of 3 mm aluminum double-sheet, 22.5 by 1.5 cm were cut, perforated, and welded at right angles to a shorter 9 cm strip. The conditioning of the samples and environment

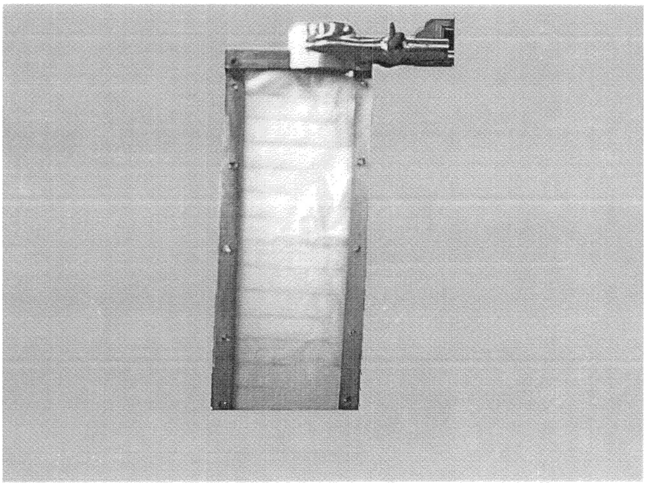

FIGURE 1 Mostashari's Flammability Tester with a fabric inserted and pinned in its internal splits, before the accomplishment of the experiment.

were in average temperature between 20°C and 22°C and at relative humidity of $65 \pm 2\%$. The fabrics were conditioned overnight before the perormance of the flammability test. It is noticeable that all specimens were pinned tightly to the frame and held vertically in a retort stand by clamps with the lower edge 1.9 cm above the top of a Bunsen burner with a 3 cm yellow flame. The ignition time was 3 s. This procedure was conducted in order to avoid the harsh circumstances of ignition. The accuracy of the burning time was determined close to the nearest 0.1 s with a stopwatch and the "char length" was measured to the nearest cm for all of the samples. The flammability test was conducted in a fume-cupboard before the completion of the combustion. However, the exhaust ventilator had been turned on for about 5 min, after each burning.

Graphical Presentations

A Windows XP system with an excel program was used, so that the relative comparative curves could be manifested. Optimum add-on values percentage of the selected anhydrous alkaline earth chlorides are reproduced from a previously propounded table [2]. However other required details concerning the physicochemical specification have been abstracted from scientific sources given in inorganic chemistry books [11–15].

TABLE 1 Comparison of Optimum Percent Efficiency Concerning Some Alkaline Earth Chlorides on the Flame-Retardancy Imparted to Cotton Fabric, with Regard to Some of the Physicochemical Characteristics

Sample formula	Percent anhydrous salt in dry samples	Atomic number of metals	Atomic weight of metals (g/mol)	Metalic radii (A°)	Covalent radii of the metal	Molecular weight of anhydrous chlorides	Melting points of the chlorides (C°)	Ionic potential of cations z/r (e/A°)	Mole anhydrous chlorides
$MgCl_2$	4.3	12	24.31	1.6	1.36	95.218	708	3.08	0.045
$CaCl_2$	5.6	20	40.08	1.97	1.74	110.986	772	2.02	0.05
$Srcl_2$	26.2	38	87.62	2.15	1.91	158.326	873	1.77	0.165
$BaCl_2$	51	56	137.34	2.22	1.98	208.246	962	1.78	0.245

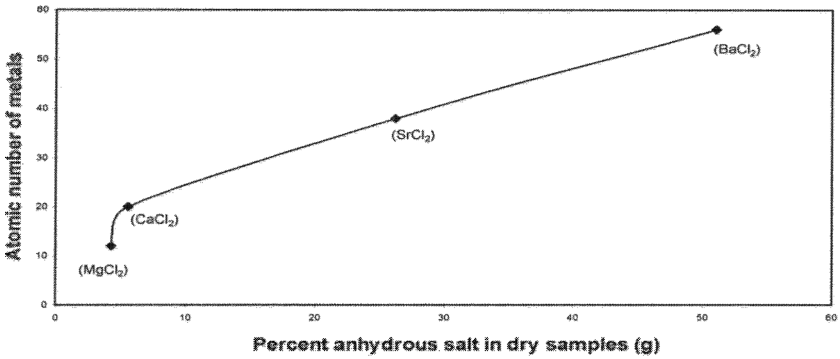

FIGURE 2 Dependence of atomic number of metals in some alkaline earth chlorides with their optimum efficient percent of add-on values corresponding to flame-retardancy.

RESULTS AND DISCUSSION

Information is summarized in Table 1 and reflects the general trends for the relationship between the optimum percent of the aforesaid anhydrous salts in dry samples to impart flame-retardancy to cotton fabric. Columns 3–8 and 10 show a reasonable systematically increases with regard to the positions of the alkaline earths in the periodic table. However, the decrease in ionic potential of cations shows

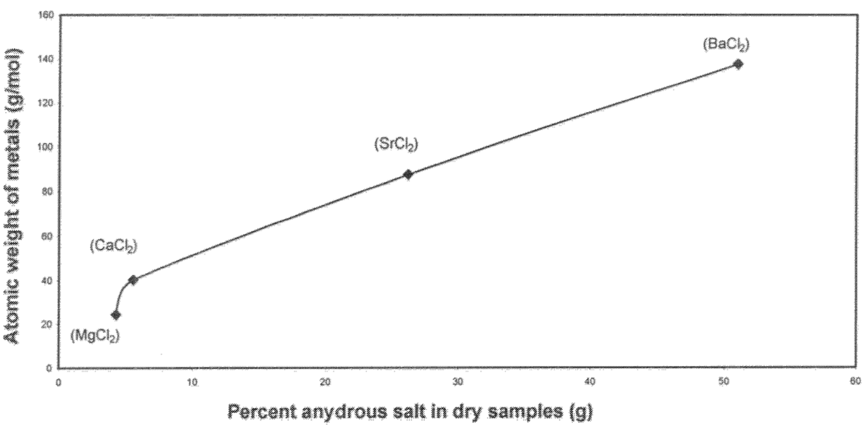

FIGURE 3 Dependence of atomic weight of metals in some alkaline earth chlorides (g/mol) with their optimum efficient percent of add-on values corresponding to flame-retardancy.

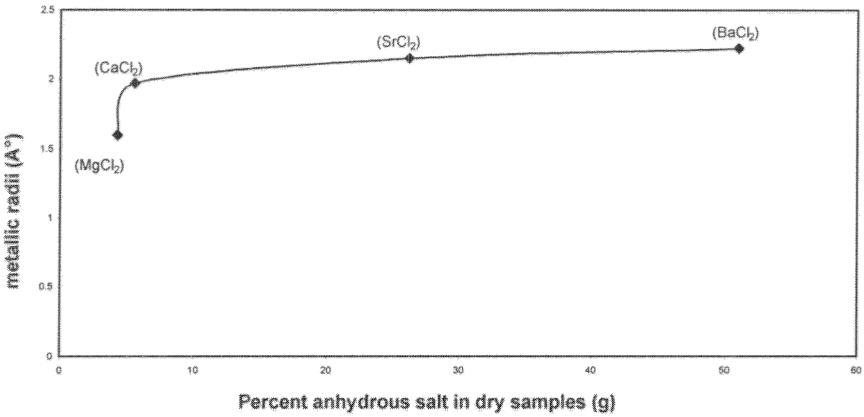

FIGURE 4 Dependence of metallic radii in some alkaline earth chlorides (A°) with their optimum efficient percent of add-on values corresponding to flame-retardancy.

also a consistency toward this relationship and expresses a systematic decrease. This trend is due to placing the radii of metal cations in the denominator fraction of the ionic potential.

Similar expressions can be seen in the graphic illustrations (Figures 2–9).

The alkaline earth chlorides have ionic nature; however, this character increases as the size of the metal increases.

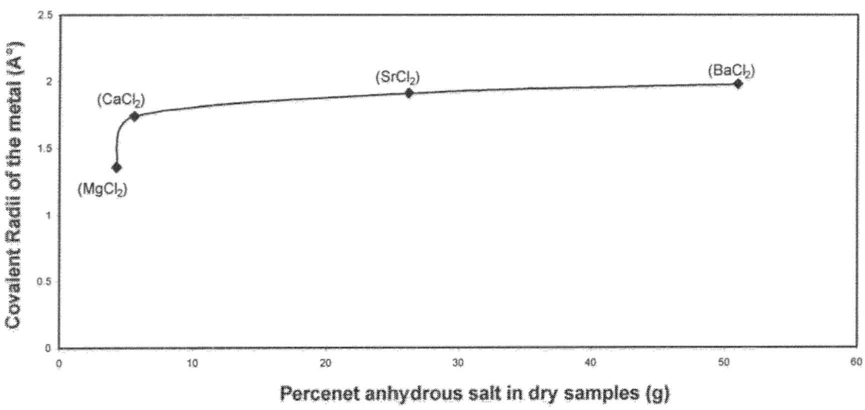

FIGURE 5 Dependence of covalent radii of metals in some alkaline earth chlorides (A°) with their optimum efficient percent of add-on values corresponding to flame-retardancy.

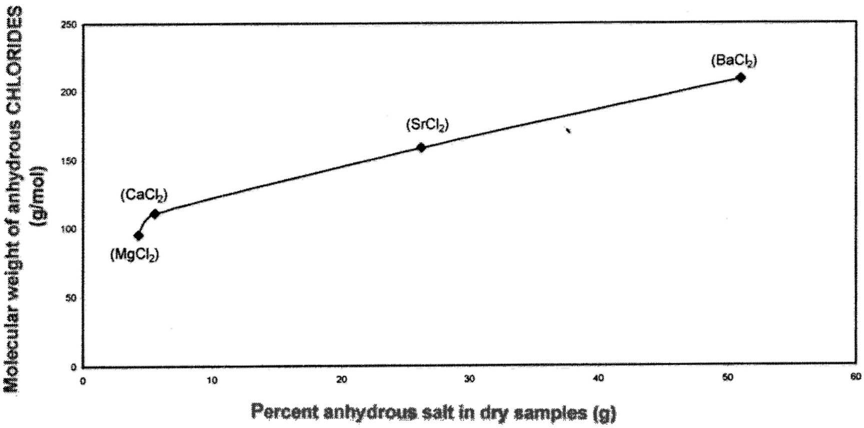

FIGURE 6 Dependence of the molecular weight of some anhydrous alkaline earth chlorides (g/mol) with their optimum efficient percent of add-on values, corresponding to flame-retardancy.

The evidence is provided by their melting points, in the series $MgCl_2$, $CaCl_2$, $SrCl_2$, and $BaCl_2$ they are 708, 772, 873 and 962°C, respectively [15]. As a result, it can also be attributed that the tendency to form covalent compounds, for example, chlorides of group (II) is characterized by their low melting points [16]. On the other hand, increasing of ΔH°_{f} of these chlorides agrees with the

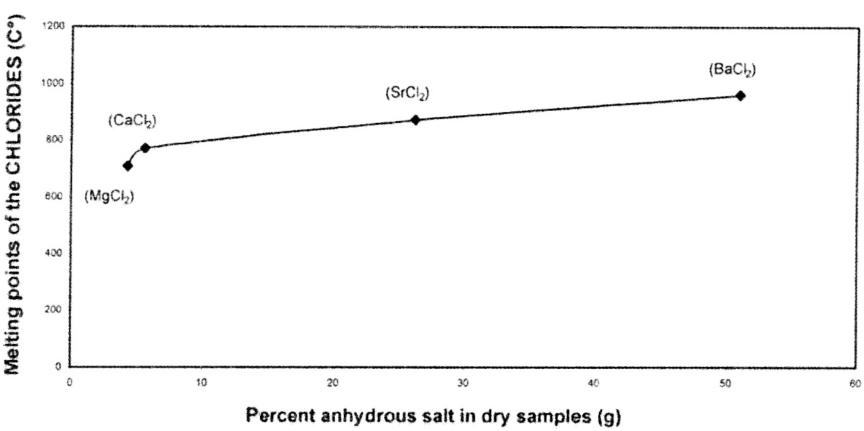

FIGURE 7 Dependence of melting points of some alkaline earth chlorides (C°) with their optimum efficient percent of add-on values, corresponding to flame-retardancy.

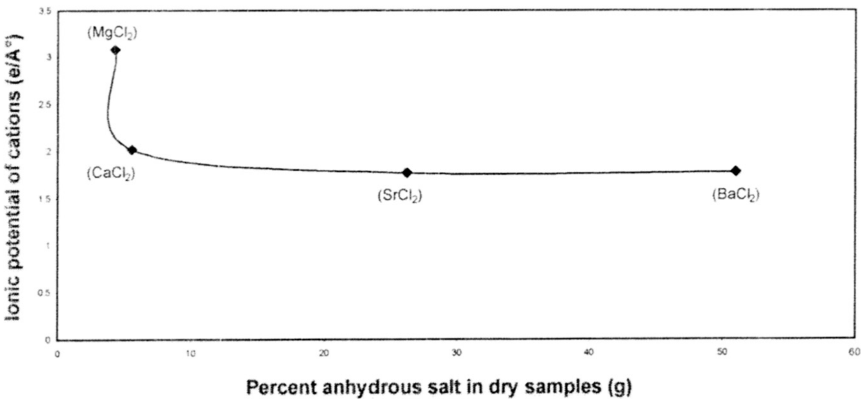

FIGURE 8 Dependence of ionic potential of cations, z/r (e/A°) in some alkaline earth chlorides with their optimum efficient percent of add-on values, corresponding to flame-retardancy.

aforementioned deduction. In fact, the standard enthalpy of formations of the selected metal chlorides show the same trend; these are $-642\,\mathrm{KJmol}^{-1}$ for $MgCl_2$, $-795\,\mathrm{KJmol}^{-1}$ for $CaCl_2$, $-828\,\mathrm{KJmol}^{-1}$ for $SrCl_2$, and $-860\,\mathrm{KJmol}^{-1}$ for $BaCl_2$ [13–15].

In one word, all of the aforementioned indications express more and more difficulties toward releasing chlorine radicals that are essential to convert the active radicals such as H, OH, O, and the like radicals

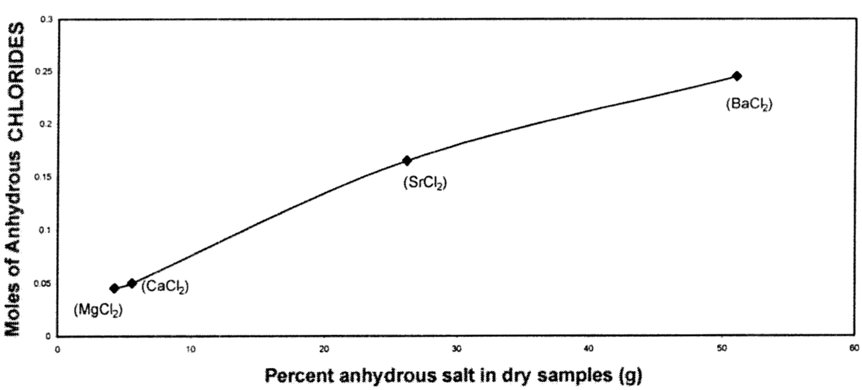

FIGURE 9 Dependence of anhydros chlorides moles in some alkaline earth metal chlorides with their optimum efficient percent of add-on values, corresponding to flame-retardancy.

released during burning process. These high energetic active radicals support combustion. So their removal via halogens such as chlorine radicals could be beneficial to quench the flame [1,5,17].

CONCLUSION

This investigation has been devoted to graphical demonstration concerning the impartation of flame-retardancy to cotton fabric by application of group II chlorides. Optimum percentages of the aforementioned compounds were picked up from the previous published article. The physicochemical specifications of these metals or their chlorides from the literature also were obtained and are shown in Table 1.

Separate descriptive graphs reveal that: With increasing the bond strength in alkaline earth chlorides, their efficiency to impart flame-retardancy decreases according to their metals positions in the periodic table.

In other words with increase of the alkaline earth cation atomic radius from Mg to Ca to Sr to Ba, the stability of corresponding chlorides increases. These increases seem to explain the observed trends in the efficiency to impart flame-retardancy, that is, the higher the stability of chlorides the lower their ability for the aforementioned propose. Hence higher quantities of them are required to achieve the same performance.

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