

Polythermal Solubility of the Magnesium Chlorate-Sulphate Triethanolamine-Water System

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ABSTRACT: The solubility of a system containing magnesium chlorate, triethanolammonium sulfate, and water was studied using the visual polythermal method. Based on the solubility polytherms of binary systems and internal sections in the temperature range from 10.0 to -56.0 °C, a polythermal solubility diagram of the $\text{Mg}(\text{ClO}_3)_2\text{-H}_2\text{SO}_4\cdot\text{N}(\text{C}_2\text{H}_4\text{OH})_3\text{-H}_2\text{O}$ system was constructed. The phase solubility diagram of the system under study shows the regions of ice, $\text{Mg}(\text{ClO}_3)_2$, $\text{Mg}(\text{ClO}_3)_2\cdot 6\text{H}_2\text{O}$, $\text{Mg}(\text{ClO}_3)_2\cdot 12\text{H}_2\text{O}$, $\text{Mg}(\text{ClO}_3)_2\cdot 16\text{H}_2\text{O}$, and $\text{H}_2\text{SO}_4\cdot\text{N}(\text{C}_2\text{H}_4\text{OH})_3$. As a result of the study, it was established that the system under study belongs to the complex eutonic type.

KEY WORDS: solubility, system, polytherm, diagram, concentration, defoliant.

I. INTRODUCTION

In Uzbekistan, cotton cultivation represents one of the most significant branches of agriculture. For the process of chemical defoliation, there is a demand for highly efficient defoliants that ensure the removal of more than 80% of leaves in a single treatment at relatively low application rates. Such defoliants are required to act gently on the plants, thereby avoiding adverse effects on seed oil content, overall yield, and the quality or purity of cotton fiber [1, 2]. However, sodium chlorate, which is currently produced and applied as a cotton defoliant in the country, does not fully satisfy the modern requirements of cotton production [3, 4]. Its relatively harsh action on plants necessitates the development of new, highly effective defoliants with a milder physiological impact.

Accordingly, considerable attention has been directed toward the synthesis of defoliants that are not only highly efficient but also low in toxicity and physiologically active. At present, chlorate-based defoliants do not meet the requirements of contemporary cotton-growing practices, as their defoliating effect is inevitably accompanied by a certain degree of desiccation [3, 5]. Within this context, the incorporation of ethanolammonium sulfate—a compound known as a plant growth stimulant—into defoliant formulations has generated significant scientific interest. The addition of this substance imparts physiological activity to the defoliant, thereby enhancing its overall effectiveness [6, 7].

II. METHODOLOGY

The present investigation considers magnesium chlorate and triethanolammonium sulphate as the primary research materials. Magnesium chlorate of chemically pure grade was subjected to recrystallization in order to obtain the purified form used in subsequent experiments. Triethanolammonium sulfate was synthesized employing 94% sulfuric acid and 90% triethanolamine in a stoichiometric ratio of 1:2. At 25 °C, the synthesized compound exists as a dense, brownish, viscous solution with a measured pH of 6.36.

The solubility polytherm of the $\text{Mg}(\text{ClO}_3)_2\text{-H}_2\text{SO}_4\cdot\text{N}(\text{C}_2\text{H}_4\text{OH})_3\text{-H}_2\text{O}$ system was determined by means of the visual polythermal method [8], with liquid nitrogen being utilized as a freezing medium during solubility studies.

Quantitative chemical characterization of the liquid and solid phases was carried out using classical analytical methods. The carbonate ion concentration (CO_3^{2-}) was established through volumetric permanganatometric titration [9].

Magnesium ion (Mg^{2+}) content was quantified using flame photometry [10], while chloride ion (Cl^-) concentration was determined by the Mohr argentometric method [11]. Elemental composition, including carbon, nitrogen, and hydrogen, was analyzed in accordance with the standard procedure described in [12].

III. EXPERIMENTAL RESULTS

The solubility of the $\text{Mg}(\text{ClO}_3)_2\text{--H}_2\text{SO}_4\text{--N}(\text{C}_2\text{H}_4\text{OH})_3\text{--H}_2\text{O}$ system was examined along seven internal sections. Based on the analysis of both binary subsystems and these sections, a comprehensive polythermal phase diagram was constructed over the temperature range -18.5 to 38.0°C .

The diagram delineates the crystallization domains of ice, magnesium chlorate, magnesium chlorate hexahydrate, magnesium chlorate dodecahydrate, magnesium chlorate hexadecahydrate, and triethanolammonium sulphate. These domains converge at two ternary invariant points, where the equilibrium solution compositions and corresponding crystallization temperatures were determined (Fig. 1, Table 1).

Solubility isotherms at 10°C intervals and projections of the polythermal curves onto the aqueous sides of the diagram were also plotted. The results confirm that the studied system belongs to the complex eutonic type.

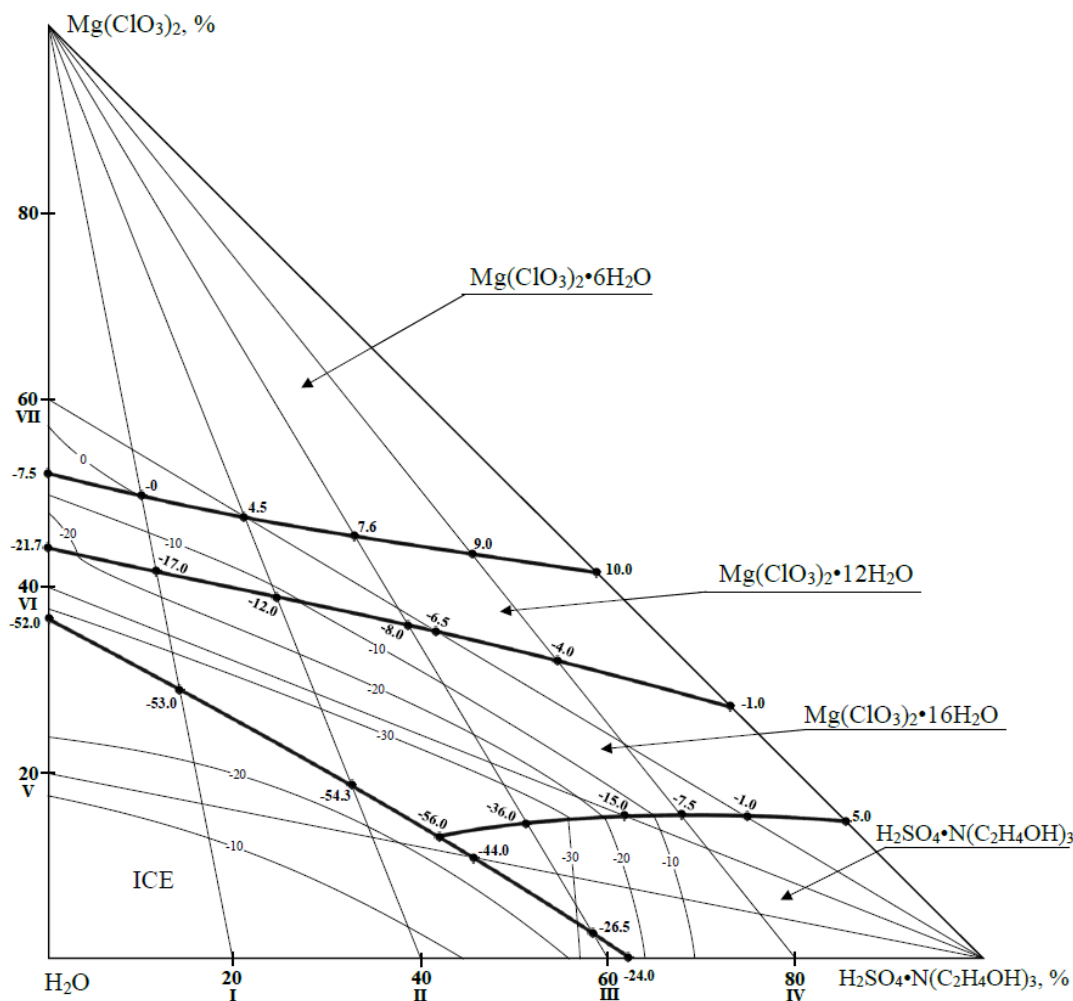


Fig 1: Solubility diagram of the $\text{Mg}(\text{ClO}_3)_2\text{--H}_2\text{SO}_4\text{--N}(\text{C}_2\text{H}_4\text{OH})_3\text{--H}_2\text{O}$ system

Table 1. Double and triple points of the system $\text{Mg}(\text{ClO}_3)_2\text{--H}_2\text{SO}_4\text{·N}(\text{C}_2\text{H}_4\text{OH})_3\text{--H}_2\text{O}$

Composition of liquid phase, %			$T_{\text{cr.}},$ °C	Solid phase
$\text{Mg}(\text{ClO}_3)_2$	$\text{H}_2\text{SO}_4\text{·N}(\text{C}_2\text{H}_4\text{OH})_3$	H_2O		
36.9	-	63.1	-52.0	Ice + $\text{Mg}(\text{ClO}_3)_2\text{·16H}_2\text{O}$
32.8	13.6	53.6	-53.0	The same
23.5	30.7	66.8	-54.3	-//-
16.0	44.0	40.0	-56.0	Ice + $\text{Mg}(\text{ClO}_3)_2\text{·16H}_2\text{O}$ + $\text{H}_2\text{SO}_4\text{·N}(\text{C}_2\text{H}_4\text{OH})_3$
10.0	49.2	40.8	-44.0	Ice + $\text{H}_2\text{SO}_4\text{·N}(\text{C}_2\text{H}_4\text{OH})_3$
2.0	58.8	39.2	-26.5	The same
-	61.4	23.8	-24.0	-//-
15.0	52.0	33.0	-36.0	$\text{Mg}(\text{ClO}_3)_2\text{·16H}_2\text{O}$ + $\text{H}_2\text{SO}_4\text{·N}(\text{C}_2\text{H}_4\text{OH})_3$
15.4	61.8	22.8	-15.0	The same
15.6	68.0	16.4	-7.5	-//-
15.3	74.6	10.1	-1.0	-//-
14.6	85.4	-	5.0	-//-
42.0	-	58.0	-21.7	$\text{Mg}(\text{ClO}_3)_2\text{·16H}_2\text{O}$ + $\text{Mg}(\text{ClO}_3)_2\text{·12H}_2\text{O}$
39.0	12.3	48.7	-17.0	The same
36.1	25.6	38.3	-12.0	-//-
33.3	40.0	26.7	-8.0	-//-
32.0	46.4	21.6	-6.5	-//-
30.0	56.0	14.0	-4.0	-//-
28.0	72.0	-	-1.0	-//-
50.2	-	49.8	-7.5	$\text{Mg}(\text{ClO}_3)_2\text{·6H}_2\text{O}$ + $\text{Mg}(\text{ClO}_3)_2\text{·12H}_2\text{O}$
47.5	10.4	42.1	0	The same
45.0	32.0	23.0	4.5	-//-
43.0	33.8	23.2	7.6	-//-
42.2	45.9	11.9	9.0	-//-
41.8	58.2	-	10.0	-//-

From the polythermal solubility diagram constructed from the study results for the $\text{Mg}(\text{ClO}_3)_2\text{--H}_2\text{SO}_4\text{·N}(\text{C}_2\text{H}_4\text{OH})_3\text{--H}_2\text{O}$ system, it is evident that the crystallization fields of magnesium chlorate hexahydrate, dodecahydrate, and hexadecahydrate are delineated.

IV. CONCLUSION AND FUTURE WORK

Thus, the results obtained from the polythermal solubility study of the $\text{Mg}(\text{ClO}_3)_2\text{--H}_2\text{SO}_4\text{·N}(\text{C}_2\text{H}_4\text{OH})_3\text{--H}_2\text{O}$ system, and the solubility diagram constructed therefrom, indicate that—while the distinct identities of the system's initial components are preserved—only magnesium chlorate hexahydrate, dodecahydrate, and hexadecahydrate are formed, and no new compound is observed. The solubility data obtained for the system's components provide the scientific basis for developing a new defoliant based on magnesium chlorate and triethanolammonium sulfate.

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