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STUDY OF THE INTERACTION OF COMPONENTS IN THE $NiSO_4$ – $(NH_4)_2SO_4$ – H_2O SYSTEM

Hakimova Xurshida Nosirjanovna [1], ***Maxkamova Dilnoza Ne'matjon qizi*** [1], ***Latifov Muhammadbobur Zokirjon o'g'li*** [1], ***Turayev Zokirjon*** [1]

[1] Namangan State Technical University, Republic of Uzbekistan, Namangan

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Abstract

To study the interaction of components in the $NiSO_4$ – $(NH_4)_2SO_4$ – H_2O system, the inflection point associated with the formation of a new phase was studied using the isomolar series method. Through this method, the interaction of nickel sulfate and ammonium sulfate in different ratios was theoretically substantiated.

Keywords: *nickel sulfate, ammonium sulfate, isomolar sequence method, pH value, density, viscosity, refractive index, crystallization temperature*

Introduction

In recent years, much research has been conducted to improve the yield and quality of agricultural crops. Proper and balanced plant nutrition with micronutrients is one of the necessary conditions for maximizing the potential yield of agricultural crops (Kulikova A. Kh., Cherkasov E. A., 2014, p. 9–25).

Microelements are not only involved in all processes of plant development and growth and are the main components of many enzymes, but are also active catalysts that accelerate a number of biochemical reactions (Kulikova A. Kh., Cherkasov E. A., 2014, p. 45–50). At the same time, micronutrients build plant immunity against bacterial and fungal diseases and increase their resistance to adverse environmental conditions, such as heat, drought, and rapid climate change (Ageev V. V., Podkolzin A. I., 2001).

The microelement nickel is one of the 17 essential elements that are important for plant development and growth (Liu G. D. 2001, p. 101–103). When nickel microelement deficiency is observed, it can directly affect symbiotic N_2 fixation, which is associated with a decrease in the activity of the symbiotic hydrogenase enzyme of the bacterium Rhizobium leguminosarum (Zobiole, L. H. S., Oliveira Jr, R. S., Kremer, R. J., Constantin, J., Yamada, T., Castro, C., & Oliveira Jr. A., 2010, p. 176–180).

Nickel is a microelement that is a component of metalloenzymes essential for life, such as carbon monoxide dehydrogenase (EC 1.2.99.2), acetyl coenzyme-A synthase (EC 2.3.1.169), acireductone dioxygenase (EC 1.13.11.54), Ni superoxide dismutase (EC 1.15.1.1.), glyoxylase (EC 4.4.1.5), urease (EC 3.5.1.5), and hydrogenase

(EC 1.12.1.2.) (Harasim P., Filipek T., 2015).

In plants, nickel is mainly absorbed through the roots, a process that occurs through passive diffusion or active transport mechanisms that require energy. Passive diffusion refers to the spontaneous movement of nickel depending on the concentration difference, while active transport occurs with the help of special proteins and with the expenditure of metabolic energy, maintaining the amount of nickel necessary for plant life (Seregin I. V., Kozhevnikova A. D., 2006, p. 257–277).

The microelement nickel plays an important role in all physiological processes in plants, from seed germination to fruiting. Without this element, plants cannot complete the full stages of ontogenesis. At the same time, high levels of nickel disrupt water metabolism, mineral nutrition, and chlorophyll structure, reducing the efficiency of photosynthesis and plant productivity (Patra A., Pradhan S. N., Dutta A., Mohopatra K. K., 2020, p. 35–37).

One of the most effective ways to obtain agricultural products of high consumer quality is to adjust the conditions for plant nutrition, that is, to establish the correct ratios between micro- and macroelements and to determine optimal doses (Pisarev B. A. 1972; Karimova V. B., Nazmieva R. R., Safiullina G. F., Zamalieva F. F., 2005, p. 171–178; Kulanovskaya T. N., 1990; Dilnoza M., Zokirjon T., Dilshoda R., 2023, p. 17–20; Xurshida H., Dilnoza M., Malika M., Zokirjon T., 2025, p. 50–53; Ne'matjon qizi Makhkamova D., Turayev Z., 2024, p. 137–144).

Microelements applied in the right amount to fertilizers improve all vital processes of the plant, including photosynthesis and mineral nutrition, and contribute to their rapid and healthy development. Therefore, the isomolar sequence method (Namangan State University. 2024, p. 145–146) was used to determine their quantity and norms when applying microelements to fertilizers.

To study the interaction of components in the $NiSO_4$ – $(NH_4)_2SO_4$ – H2O system, the inflection point associated with the formation of a new phase was studied using the isomolar series method. Through this method, the interaction of nickel sulfate and ammonium sulfate in different ratios was theoretically substantiated. During the study, isomolar solutions of components with the same molar concentration were mixed in certain ratios based on the isomolar series method, and experimental analyses were carried out while maintaining a constant sum of the initial volumes. Based on the results obtained, the complex formation process of nickel sulfate and ammonium sulfate was explained using graphical analysis.

Materials and Methods

To theoretically substantiate the interaction of nickel sulfate and ammonium sulfate, the physicochemical properties of diluted solutions were analyzed using the isomolar series method by measuring the pH, density, refractive index, and viscosity values of the 0.01 M solution mixture based on the ratio of components in the ($NiSO_4$ (0.01 M)) : (($NH_4)_2SO_4$ (0.01 M)) system.

For the study, 0.01 M nickel sulfate and 0.01 M ammonium sulfate solutions were initially prepared. Then, a gradually increasing amount of ammonium sulfate solution was added to the nickel sulfate solution. The pH value, refractive index, viscosity, and density of the resulting mixtures were determined. All measurements were carried out in a water thermostat at a temperature of 20 ± 0.1 °C.

The kinematic viscosity of the solution was measured with an accuracy of $\pm 0.0001 \cdot 10^{-1}$ mm²/s using a 0.82 mm diameter VPJ-4 capillary viscometer. The relative density was determined using a pycnometric analysis method (Zdanovsky A. B., Hallurgy, 1972). The pH of the solution was measured using a FiveGo™ F2 Mettler-Toledo pH apparatus.

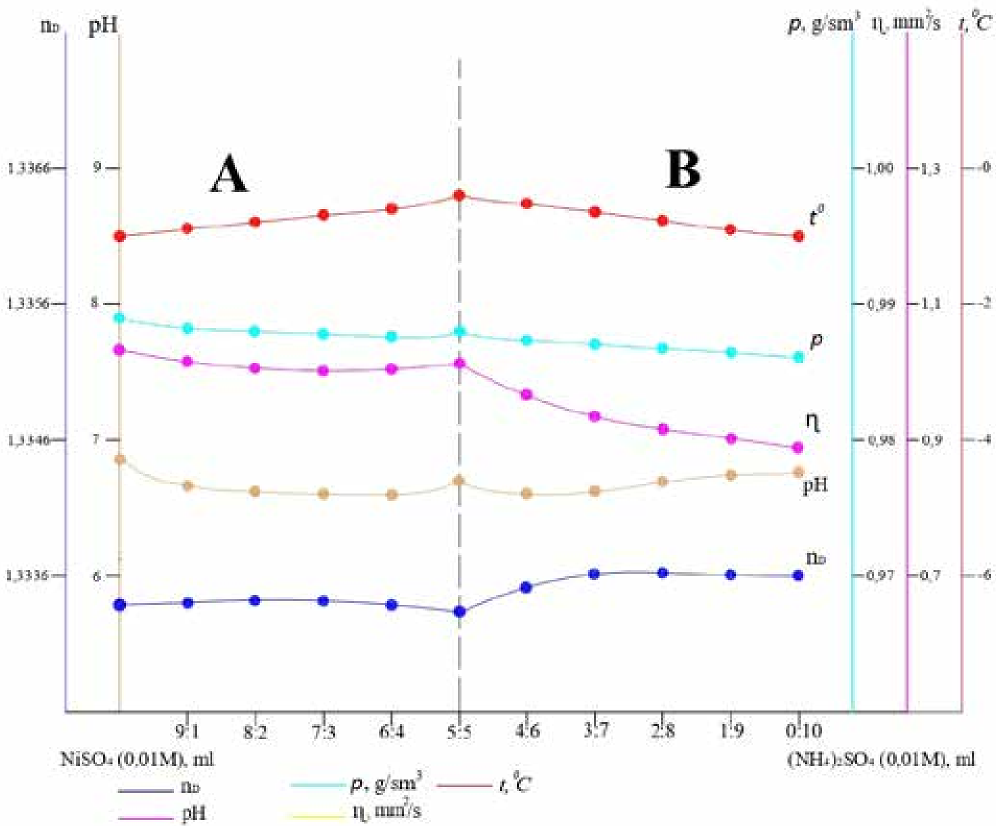
The results of the dependence of the change in the physicochemical properties of solutions on the ratio of components in the $NiSO_4$ and $(NH_4)_2SO_4$ system are shown in Table 1and Figure 1.

Results and discussion

Analysis of the "pH - composition" diagram in the system ($NiSO_4$ (0.01M)): :(($NH_4)_2SO_4$ (0.01 M)) shows that with an increase in the amount of 0,01 M ammonium sulfate solution from 3 ml to 30 ml, the pH values of the solutions decrease from 6,85 to 6,77, and with a ratio of

($NiSO_4$ (0,01 M)):(($(NH_4)_2SO_4$ (0,01M))=5:5, a break is observed at a pH value of 6,68. This characteristic of the pH value change indicates the formation of a new compound resulting from the chemical reaction between ($NiSO_4$ (0,01 M)) and (($(NH_4)_2SO_4$ (0,01 M)).

Figure 1. *Changes in the physicochemical properties of solutions depending on the ratio of components in the system ($NiSO_4$ (0.01 M) + $(NH_4)_2SO_4$ (0.01 M))*



In the " Composition – Density" diagrams, with an increase in the amount of ammonium sulfate and a decrease in the amount of nickel sulfate, the density of the solutions gradually decreases from 0.9889 g/cm³ to 0.9648 g/cm³, and a change in the density value to 0.9883 g/cm³ is observed with a composition ratio of ($NiSO_4$ (0.01 M)):(($(NH_4)_2SO_4$ (0.01 M))= = 5:5. This change may be due to the interaction between the ions of the ammonium sulfate and nickel sulfate solutions and the formation of a new compound.

Table 1. *Changes in the physicochemical properties of solutions depending on the ratio of components in the system ($NiSO_4$ (0.01 M) + $(NH_4)_2SO_4$ (0.01 M))*

№	Composition of components		pH	Density, g/cm³	Viscosity, mm²/c	Refractive index	Crystallization temprature, °C
	$NiSO_4$, ml	$(NH_4)_2SO_4$, ml					
1	30	0	6,85	0,9889	1,0341	1,33340	-1,0
2	27	3	6,67	0,9883	1,0140	1,33350	–0,9
3	24	6	6,61	0,9879	1,0041	1,33350	–0,8
4	21	9	6,59	0,9878	1,0021	1,33350	–0,7
5	18	12	6,60	0,9876	1,0012	1,33350	–0,6
6	15	15	6,68	0,9883	1,0051	1,33345	–0,4

№	Composition of components		pH	Density, g/cm^3	Viscosity, mm^2/c	Refractive index	Crystallization temprature, °C
	$NiSO_4$, ml	$(NH_4)_2SO_4$, ml					
7	12	18	6,61	0,9878	0,9651	1,33360	–0,5
8	9	21	6,62	0,9871	0,9361	1,33370	–0,6
9	6	24	6,72	0,9865	0,9142	1,33370	–0,8
10	3	27	6,75	0,9855	0,8960	1,33370	–0,9
11	0	30	6,77	0,9648	0,8810	1,33370	–1,0

Analysis of the data of the "Composition – refractive index" diagram shows that the refractive indices in the system gradually decreased from 1,33340 to 1,33345 up to the ratio ($NiSO_4$ (0.01 M)):($(NH_4)_2SO_4$ (0.01 M))= = 5 : 5, and it can be noted that there was a significant break in the diagram. With increasing ammonium sulfate content in the mixture, the refractive index value continued to decrease to 1,33370.

The viscosity values of the solution of the studied system decrease from 1.0341 mm^2/s to 0.8810 mm^2/s with a decrease in the amount of 0.01 M nickel sulfate and an increase in the amount of 0.01 M ammonium sulfate, which is also explained by the presence of a breaking point of 1.0051 mm^2/s at a ratio of 5:5.

In the "Composition-Crystallization Temperature" diagram, as the amount of 0.01M ammonium sulfate solution increases from 3 ml to 30 ml and the amount of nickel sulfate decreases from 30 ml to 0 ml, the crystallization temperature of the solutions rises from –1 °C to –0.4 °C, with a breaking point observed. Additionally, as the amount of ammonium sulfate in the solution increases, the temperature drops to –1 °C.

Conclusion

In summary, to study the interaction of micronutrient salts with mineral fertilizer components, using 0.01 M solutions of ammonium sulfate and nickel sulfate, an isomolar series method was investigated, and the hydrogen index of the mixtures, density, viscosity, crystallization temperature, and refractive index characteristics were studied.

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Contact: dilnozamaxkamova_7007@mail.ru