THE EDUCATIONAL AND METHODOLOGICAL SIGNIFICANCE OF SPECTROPHOTOMETRIC DETERMINATION OF NI(II) ION

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Abstract: This article highlights the educational and methodological significance of the spectrophotometric method in the determination of Ni(II) ions. The study analyzes the opportunities for developing students' skills in analytical chemistry within higher education chemistry laboratories, teaching the use of modern instrumental analysis methods, linking theoretical knowledge with practical applications, and fostering independent thinking as well as scientific research competencies.

Keywords: spectrophotometry, Ni(II) salt, analytical chemistry, instrumental methods, laboratory methodology, educational effectiveness.

Introduction. At present, methods for the determination of metal ions hold a particular significance in the field of analytical chemistry. Nickel(II) ions are among the important elements frequently encountered in industry, ecology, and biological systems. Therefore, teaching the spectrophotometric determination of Ni(II) ions in higher education institutions plays an essential role in developing students' practical skills. Scientific sources indicate that organizing chemistry education through interactive methods fosters students' independent thinking, research abilities, and practice-oriented competencies [1; 2]. Furthermore, the use of virtual laboratories, multimedia tools, and electronic textbooks enhances the effectiveness of the teaching process [3].

Spectrophotometry is currently one of the most widely applied instrumental methods, distinguished by its advantages such as rapid performance, high sensitivity, and applicability under simple laboratory conditions. The use of this method in the determination of Ni(II) ions helps students develop not only laboratory culture but also scientific analytical skills.

Literature Review

In writing this article, a number of works published by professors and researchers in the field of analytical chemistry were utilized. These include the following:

Turabov N.T., Meliyeva S.S., Turayeva G.S., Todjiyev J.N. Application of 5-methyl-2-methoxy-4-sulfophenylazo-2'-hydroxy-6'-naphthalenesulfonic acid in analytical chemistry // Chemistry and Technology of Rare and Noble Metals: Current State, Challenges, and Prospects. Proceedings of the Republican Scientific-Practical Conference. – Termez, 2023. – pp. 207–208.

Toychiyeva Kh.Ch., Turayeva G.S., Meliyeva S.S., Todjiyev J.N. 5-methyl-2-methoxy-4-sulfophenylazo-2'-hydroxy-6'-naphthalenesulfonic acid as an analytical reagent // Topical Issues of Analytical Chemistry. Proceedings of the International Republican Scientific-Practical Conference. – Tashkent, May 11–12, 2023. – pp. 73–74.

Todjiyev J.N., To'rayeva G.S., Raupova S.S., Tuliyev B.A. Analytical characteristics of 5-methyl-2-methoxy-4-sulfophenylazo-2'-hydroxy-6'-naphthalenesulfonic acid and optimal conditions of its complexation reaction with Ni(II) ion // Fundamental and Applied Problems of

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Physical and Colloid Chemistry and Their Innovative Solutions. Proceedings of the International Scientific-Practical Conference. – Namangan, 2024. – pp. 434–440.

Todjiyev J., Turabov N., Turayev Kh., Turayeva G., Raupova S., Tashpulatova Z. Monitoring of trace amounts of Fe(III) and Cu(II) ions as environmental factors and development of spectrophotometric methods for their detection // Bulletin of the National University of Uzbekistan. – Tashkent, 2024. – Vol. 3, No. 2(1). – pp. 420–423. ISSN 2181-7324. URL: http://journals.nuu.uz.

Turabov N.T., Todjiyev J.N., Turayev Kh.Kh., Raupova S.S., Usmanova M.D., Smanova Z.A. Influence of heavy metal ions on environmental pollution // Uzbekistan Compositional Materials, Scientific-Technical and Applied Journal. – Tashkent, 2024. – No. 4. – pp. 204–206. ISSN 2091-5527.

As noted in the literature, determining the optimal conditions (pH, reagent concentration, stability of the complex) is of great importance in the identification of Ni(II) ions. It is precisely these stages that students learn during practical laboratory sessions.

Materials and Methods. In the development of a spectrophotometric method for the determination of Ni(II) ions using 5-methyl-2-methoxy-4-sulfophenylazo-2'-hydroxy-6'-naphthalenesulfonic acid as a reagent, standard Ni(II) ion solutions, buffer solutions suitable for the medium, a spectrophotometer (EMC-30PC-UV), and other laboratory equipment were employed.

Research methods included the following:

Complex formation. Ni(II) ions form colored complexes with 5-methyl-2-methoxy-4-sulfophenylazo-2'-hydroxy-6'-naphthalenesulfonic acid and other reagents, during which a change in solution color is observed.

Spectral measurements. The maximum absorption wavelength (λ_{max}) of the resulting complexes was determined using a spectrophotometer.

Calibration curve. The relationship between absorbance and concentration was established using standard solutions.

Analysis of unknown solutions. Students were tasked with determining the concentration of Ni(II) ions in unknown solutions based on the calibration graph.

Methodological approach. During the experiments, students were provided with step-by-step instructions, error sources were analyzed, and data processing methods were taught.

Experimental part. This study focused on investigating various physicochemical characteristics of 5-methyl-2-methoxy-4-sulfophenylazo-2'-hydroxy-6'-naphthalenesulfonic acid, including absorption spectra, calibration curves using standard solutions, stoichiometric ratios of reagent-to-complex formation, and optimal experimental conditions.

Determination procedure. In a 25 ml volumetric flask, 5 ml of a universal buffer solution with a pH range of 4.1–11.5, 1.0 ml of 0.05% solution of 5MMSGNS reagent, and 1.0 ml of a 50 µg/ml Ni(II) ion solution were added, then diluted to the mark with distilled water.

Analytical and Metrological Characteristics Identified During the Study. The research results demonstrated that the optical density of the complex is 365 nm, the optimal medium is pH 9.2, the reagent volume is 1.2 ml, and the stability of the complex with respect to time is 2 hours. The universal buffer solution was used. The spectral characteristic of the reagent was found to be λ_{HR} = 500 nm, with contrast $\Delta\lambda$ = 135 nm. The actual molar absorption coefficient of the complex was ε_{act} = 12,658, while the equilibrium constant was Km = $1.529 \cdot 10^{-11}$. The actual molar absorption coefficient of 5-methyl-2-methoxy-4-sulfophenylazo-2'-hydroxy-6'-naphthalenesulfonic acid was ε_{act} = 2482.1. The molar composition of the complex was Ni:R = 1:2. The linearity range according to the Beer–Lambert–Bouguer law was 1.0–35.0 µg/25 ml,

with a detection limit of 0.4521 μg/25 ml. Sensitivity by Sandell's criterion was Sb.s = 0.0052 μg/cm², and the relative standard deviation was SA = 0.00234.

Results and Discussion. In the educational process, the use of interactive methods such as "Cluster," "Insert," and "Brainstorming" increased students' engagement.

Cluster method. The cluster method is a visual teaching tool where the central concept is placed in the center and related ideas branch out from it. For the topic "Spectrophotometric determination of Ni(II) ions", the cluster may be structured as follows:

Central concept: Spectrophotometric determination of Ni(II) ions.

Basis: essence of spectrophotometry, sensitivity, selectivity, rapidity.

Materials: spectrophotometer, $NiSO_4$ solutions, chromogenic reagents, buffer solutions.

Methods: complex formation, determination of λmax, construction of calibration graph, analysis of unknown solution.

Results: λ_{max} = 365 nm, stability of the complex (up to 200 min), optimal pH = 9.2.

Educational significance: development of students' skills, independent analysis, integration of theory and practice.

Teaching this topic through the cluster method allows students to:

-visualize complex chemical processes in a systematic way;

-integrate theoretical knowledge with laboratory practice;

-better understand the didactic significance of spectrophotometric methods.

Insert method. The INSERT method is based on marking information as follows: "V" – prior knowledge, "+" – new information, "–" – contradictory/unexpected information, "?" – unclear points requiring explanation.

For the topic "Spectrophotometric determination of Ni(II) ions":

1.   **V (prior knowledge):** Spectrophotometry is an analytical method based on light absorption.

2.   **+ (new):** Ni(II) ions form colored complexes with 5MMSGNS reagent at 365 nm.

3.   **– (unexpected):** The stability of the complexes up to 200 minutes was an unanticipated result.

4.   **? (question):** Why does the method yield poor results at pH values other than 9.2?

Advantages of using the INSERT method include:

-engaging students as active participants;

-comparing theoretical and practical data;

-consolidating knowledge and identifying errors;

-encouraging independent inquiry.

Brainstorming method. In the brainstorming approach, the teacher poses a problem or question, and students freely express their ideas and suggestions. Example questions for this topic include:

1.   What difficulties arise in detecting Ni(II) ions with conventional chemical methods?
2.   What advantages does spectrophotometry have over other methods?
3.   Which reagents are the most sensitive to Ni(II) ions?
4.   How would choosing the wrong λ_{max} affect the results?
5.   What types of errors might students make during the laboratory experiment?

Students' responses included:

•   Conventional methods are not sensitive enough.

•   Spectrophotometry is fast and accurate.

•   5-methyl-2-methoxy-4-sulfophenylazo-2'-hydroxy-6'-naphthalenesulfonic acid is a widely used reagent.

•   Incorrect λ_{max} selection leads to significant errors in concentration determination.

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- Sources of error: inaccuracies in solution preparation, improper adjustment of the spectrophotometer, etc.

The brainstorming method provided students with opportunities to:

-express their knowledge freely;

-discuss experimental challenges and propose different ideas;

-recognize the importance of creativity in analytical chemistry;

-reinforce their understanding through teacher-guided conclusions.

Conclusion. Spectrophotometric determination of Ni(II) ions is an effective method for higher education chemistry laboratories. It enables students to master modern instrumental techniques, develop analytical skills, and foster scientific inquiry and critical thinking.

Introducing this experiment into the analytical chemistry curriculum enhances the effectiveness of the learning process and plays a significant role in preparing students for research activities. Moreover, the use of interactive methods such as "Cluster," "Insert," and "Brainstorming" ensures effective organization of analytical chemistry lessons, promotes deeper assimilation of experiments, strengthens questioning skills, encourages independent inquiry, and prepares students for scientific research.

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