SPECTROPHOTOMETRIC DETERMINATION OF VANADIUM(IV) ION USING XYLENOL ORANGE REAGENT

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Abstract: The determination of vanadium(IV) ions in environmental and industrial samples is an important analytical task due to their biological and ecological significance. In this study, a spectrophotometric method for the determination of vanadium(IV) ions is proposed. Xylenol Orange was selected as a sensitive analytical reagent, and the reflectance spectra of the vanadium(IV)–Xylenol Orange system were recorded using an EMC-30PC-UV-1800 UV–Vis spectrophotometer. The optimal conditions for complex formation, including pH and reaction time, were investigated. The developed method demonstrated good sensitivity, selectivity, and reproducibility, making it suitable for the determination of vanadium(IV) ions in real samples.

Key words: vanadium(IV), Xylenol Orange, reagent, spectrophotometric, complex formation.

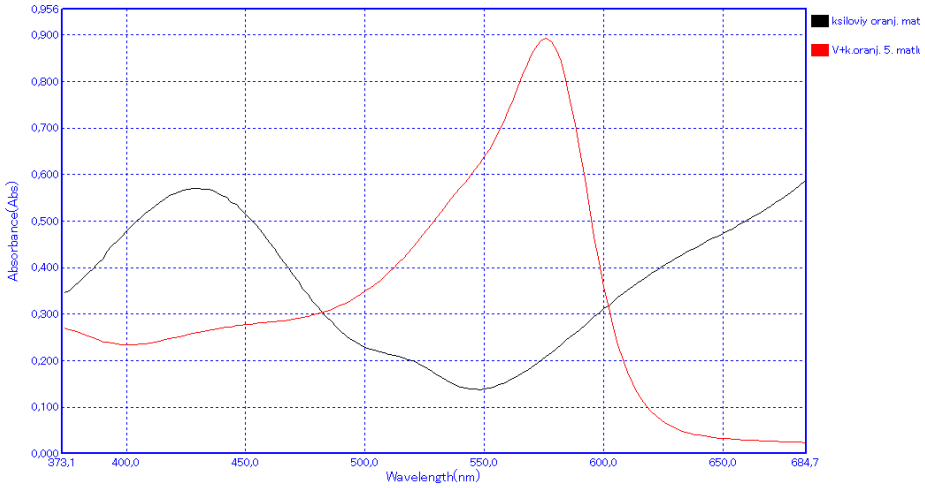
Introduction. Vanadium is one of the elements of significant importance in biological, ecological, and industrial processes. It exists in various oxidation states, with vanadium(IV) and vanadium(V) being the most common forms in aqueous solutions, and their toxicity as well as biological effects depend on the oxidation state [1]. Therefore, the determination of vanadium ions and the differentiation of their oxidation states is one of the important tasks of modern analytical chemistry [1,2]. At present, various instrumental methods are used for the determination of vanadium, including atomic absorption spectroscopy, inductively coupled plasma techniques (ICP-OES, ICP-MS), and electrochemical methods. However, these methods often require expensive equipment and complex sample preparation procedures [2]. For this reason, simple, cost-effective, and reliable spectrophotometric methods are still widely applied [2,3]. Spectrophotometric methods are generally based on the formation of colored complexes between metal ions and organic reagents, providing high sensitivity and selectivity [3]. In particular, metallochromic indicators such as Xylenol Orange are known for their ability to form colored complexes with many metal ions, including vanadium [3,4]. Studies have shown that Xylenol Orange forms stable colored complexes with vanadium in acidic media, which provide a suitable analytical signal for spectrophotometric determination [4,5]. Recent studies have demonstrated that methods based on Xylenol Orange exhibit high sensitivity (at the μg/L level), good reproducibility, and short analysis time [1,5]. In addition, differences in the kinetics of complex formation allow the simultaneous determination of vanadium(IV) and vanadium(V) [1]. Therefore, the development and improvement of spectrophotometric methods for the determination of vanadium(IV) ions

using Xylenol Orange are of great importance for environmental monitoring and the analysis of industrial samples.

Methods. At present, various methods are available for the determination of vanadium(IV) ions in environmental samples; however, certain limitations restrict their practical application. Among these methods, spectrophotometric techniques are widely used due to their simplicity, high sensitivity, and relatively low cost.

In this study, a spectrophotometric method for the determination of vanadium(IV) ions was developed. Xylenol Orange was selected as an organic analytical reagent. Vanadium(IV) ions form a colored complex with Xylenol Orange in an acidic medium, which serves as the basis for spectrophotometric determination.

The reflectance spectra of the vanadium(IV)–Xylenol Orange system were measured relative to a reference solution using an EMC-30PC-UV-1800 UV–Vis spectrophotometer. During the experiments, the optimal conditions for complex formation, including the pH of the medium, reagent concentration, and reaction time, were investigated.



1-picute. Spectrum of the immobilized Xylenol Orange complex with V(IV) ions: 1 – Xylenol Orange (λmax = 432 nm); 2 – V(IV)–Xylenol Orange complex (λmax = 578 nm).

The obtained results showed that the maximum absorption wavelength of Xylenol Orange was λmax = 432 nm, whereas the maximum absorption wavelength of its complex with vanadium(IV) ions was observed at λmax = 578 nm. Thus, the difference in wavelengths was Δλ = 146 nm. Such a significant bathochromic shift confirms the formation of a colored complex between vanadium(IV) ions and Xylenol Orange. The high contrast of the reaction indicates that Xylenol Orange can be successfully used as a sensitive analytical reagent for the spectrophotometric determination of vanadium(IV) ions.

Results: To determine vanadium(IV) ions, technogenic water samples from the Shurtan Oil and Gas Production Department located in the Kashkadarya region were used, and the amount of vanadium was determined using the introduction–recovery method.

Table 1

Results of the spectrophotometric determination of vanadium(IV) ions in wastewater from the Shurtan Oil and Gas Production Department

(n = 5; P = 0.95)

MeO^{2+}	Entered, mg/l	Found, mg/l	**S**	S_r
VO^{2+}	1,00	1,0±0,04	0,076	0,052
	1,50	1,54±0,06	0,055	0,038
	2,00	2,05±0,09	0,083	0,04

The results of the analysis showed that during the determination of vanadium(IV) ions in wastewater from the Shurtan Gas Processing Complex, the value of Sr did not exceed 0.052. This indicates the reliability and good reproducibility of the obtained results. Therefore, the developed method allows the determination of vanadium(IV) ions in various natural objects.

Conclusion: The developed method enables the determination of vanadium(IV) ions, and the mechanism of complex formation between vanadium ions and the Xylenol Orange reagent was investigated. The optimal conditions for the reaction, the influence of interfering ions, and the component ratios were established. The low values of S and Sr indicate that the method has high accuracy and reproducibility. The proposed spectrophotometric method is simple, sensitive, and selective, and it can be widely applied for the determination of vanadium(IV) ions in environmental and industrial samples.

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