

Extraction-Spectrophotometric Determination of Titanium With 2,6-Dimercapto-4-Isopropylphenol and Hydrophobic Amines

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Abstract

A very simple, rapid and sensitive spectrophotometric procedure for the determination of trace amounts of titanium (IV) is described using 2,6-dimercapto-4-isopropylphenol as a new reagent in the presence of a hydrophobic amine. Of the hydrophobic amines, aniline, *N*-methylaniline and *N,N*-dimethylaniline were used. Titanium (IV) was reacted with 2,6-dithiol-4-isopropylphenol and hydrophobic amines in a weakly acidic medium at pH 3.3-4.6 using acetate buffer solution to form an orange colored stable complex of 1:2:2 composition with a maximum absorption at 438-446 nm. The complex is formed instantly and remains stable for 2 hours. Beer's law is observed in the range of 0.05-12 $\mu\text{g ml}^{-1}$ with a molar absorptivity of $(2.50-2.68) \times 10^4 \text{ L mol}^{-1} \text{ cm}^{-1}$. The proposed methods have been successfully applied to the determination of titanium in metallic aluminum, wastewater and seawater.

Keywords: Spectrophotometry, Titanium (IV), 2,6-Dimercapto-4-Isopropylphenol, Extraction

1. Introduction

Titanium exists in nature in its most common oxidation state as titanium (IV). Titanium compounds have high corrosion resistance to chloride solutions including seawater, nitric acid and other bleaches. Titanium dioxide is used as a white pigment in paints. On the other hand, the paint, pigment, paper and pulp industries discharge very large quantities of titanium, so the determination of trace amounts of titanium is becoming increasingly important. Various analytical methods have been used for the determination of titanium (IV), including high-performance liquid chromatography using 5,5'-methylenediamine salicylohydroxamic acid, voltammetry using a carbon paste electrode modified with cetyltrimethylammonium bromide, inductively coupled plasma atomic emission spectrometry, and spectrophotometry [1]. Spectrophotometric methods occupy a special place in the determination of titanium due to their simplicity, less expensive equipment and high sensitivity.

Titanium is one of the elements for which many methods have been developed for its determination. The most widely used methods are those using tyron, chromotropic acid, and diantipyrylmethane. The most sensitive methods include the thiocyanate method (with extraction) and methods using fluorones [2]. Reagents containing hydroxy and carboxy groups, or two hydroxy groups in the ortho position to each other, interact with titanium primarily in weakly acidic solutions to form colored complex compounds [3]. 2-hydroxy-5-chlorothiophenol, 2-hydroxy-5-bromothiophenol, and 2,6-dithiol-4-*tert*-butylphenol

have been used to determine titanium [4-7]. Methods for spectrophotometric determination of titanium in waste and sea water have been developed. aluminum alloys, silicate rocks, metallic aluminum and artificial mixtures [8-15]. This work is devoted to spectrophotometric research mixed-ligand complexes (MLC) of titanium with 2,6-dimercapto-4-isopropylphenol (DTIPP) and hydrophobic amines (Am), as well as the study of their spectrophotometric characteristics. Aniline (An), *N*-methylaniline (mAn) and *N,N*-dimethylaniline (dAn) were used as hydrophobic amine.

2. Materials and Methods

2.1. Reagents and solutions: The stock solutions ($2.08 \cdot 10^{-2}$ M) of Ti (IV) were prepared as follows: 0.835 g of pure TiO_2 , calcined at a temperature of 900 °C, was fused with 8 g of $\text{K}_2\text{S}_2\text{O}_7$ in a quartz crucible. The transparent melt was cooled and dissolved in 150 ml of hot H_2SO_4 (1:2). After cooling, the solution was diluted with sulfuric acid (1:5) in a 500 ml measuring flask [2]. The concentration of the titanium solution was established gravimetrically - by precipitating titanium as titanium hydroxide and weighing TiO_2 [16]. Working solutions with a concentration of 0.1 mg/ml were obtained by diluting the stock solution with 0.5 M sulfuric acid. A 0.01 M DMIPP solution was used in the work. Aniline (An), *N*-methylaniline (mAn) and *N,N*-dimethylaniline (dAn) were used in freshly distilled form. Purified chloroform was used as an extractant. DMIPP was purified by reprecipitation from ethanol solutions by adding water and then distillation. A constant ionic strength of $\mu=0.1$ was maintained by introducing a calculated amount of KCl. A 0.1 M HCl solution

and acetate buffer were used to create the required acidity of the solutions.

2.2. Equipment: The optical density of the organic phase was measured on a KFK-2 and Shimadzu UV1240. The equilibrium pH of the aqueous phase was measured on an I-120.2 device with a glass electrode. IR spectra were recorded using a Bruker spectrophotometer. The NMR spectra of the reagents were recorded on a pulsed Fourier spectrometer from Bruker (Germany), at an operating frequency of 300.18 MHz, in solutions of deuterated benzene at room temperature. The process of thermolysis of compounds was studied using a derivatograph of the Shimadzu system. TGA -50 H » in air in the range of 20-1000 °C, heating rate -10 deg/min. The studied substances and the standard were heated in platinum crucibles.

2.3. Methodology: 0.1-0.8 ml of the initial titanium solution, 2.4 ml of 0.01 M DMIPP solution and 2.2 ml of 0.01 M Am were introduced into graduated test tubes with ground stoppers in the specified sequence with an interval of 0.1 ml. The required pH value was set by adding 2 ml of 1 M HCl solution and 5 ml of acetate buffer. The volume of the organic phase was brought to 5 ml with chloroform, and the aqueous phase to 20 ml with distilled water. After complete phase separation, the organic layer was separated, and its optical

density was measured at room temperature on a KFK-2 at 440 nm ($l = 0.5$ cm).

3. Results and Discussion

The presented work is devoted to the spectrophotometric study of the interaction of titanium with 2,6-dimercapto-4-isopropylphenol. DMIPP with titanium forms a colored complex insoluble in non-polar organic solvents. Experiments on electromigration in a U-shaped tube and on anion exchange on an EDE-10 P anion exchanger showed the anionic character of the homogeneous ligand complex. When hydrophobic amines are introduced into the system, extraction of the anionic complex into the organic phase in the form of MLC is observed. Of the hydrophobic Am, aniline, N-methylaniline, N,N-dimethylaniline were used. Based on the data obtained, new highly sensitive methods for photometric determination of Ti microquantities in different objects were developed.

The complexing reagent DMIPP is a tribasic weak acid (H3R) and, depending on the pH of the medium, can exist in molecular and two anionic forms. The reagents were synthesized using a well-known method [17] and characterized by physicochemical methods: IR and NMR spectroscopy [18,19] (Table 1).

Reagent	IR (K Br)	¹ H NMR (300.18 MHz, C ₆ D ₆)
DMIPP	3465 cm ⁻¹ ν(OH), 3050 cm ⁻¹ ν(CH), 2572 cm ⁻¹ ν(SH), 2950 and 2874 cm ⁻¹ ν(-CH ₃), 1565 cm ⁻¹ δ(C ₆ H ₅), 1460 cm ⁻¹ δ _{as} (-CH ₂ -CH ₃).	δ 5.39 (s, 1H-OH), δ 3.42(s, 2H - 2SH), δ 7.21 (s, 2H Ar-H), δ 2.59 (s, 2H -CH ₂ -), δ 1.22 (s, 3H -CH ₃).

Table 1: Results of IR and NMR Spectroscopy Studies

Reagent	Exit, %	<i>d</i> ₄ ²⁰	<i>n</i> _D ²⁰	M.R.D.		Found, %					
				Found	Calculated	Theoretical			Practically		
						C	O	S	C	O	S
DMIPP	55	1.1868	1.6214	59.30	59.18	54.00	8.00	32.00	54.08	8.12	32.09

Table 2 Some Physical Constants and Elemental Analysis of DMIPP

For the extraction of MLC, the following nonaqueous solvents were tested: chloroform, 1,2-dichloroethane, carbon tetrachloride, benzene, chlorobenzene, toluene, xylene, isobutanol, isopentanol and diethyl ether. The extractability of the complexes was estimated by the distribution coefficient and the degree of extraction. The best extractants were chloroform, dichloroethane and carbon tetrachloride. With a single extraction with chloroform, 97.7-97.9% of titanium is extracted in the form of MLC. Further studies were carried out with chloroform. The purity of the chloroform used has a significant effect on the intensity of the color of the extracts. The presence of alcohol in it reduces the absorption of the extracts. The titanium content in the organic phase was

determined photometrically with Tiron after reextraction, and in the aqueous phase - by difference.

The effect of acidity on complex formation was studied in the pH range of 1-6. When determining titanium DMIPP, it is necessary to strictly observe the pH value of the medium established for the method. For this purpose, an acetate buffer mixture (pH 3.5-5.0) was used. For the formation and extraction of ionic associates, pH 3.3-4.6 is optimal. At pH ≈ 1 and below, the optical density of the resulting complexes decreases noticeably, which is obviously due to a decrease in the concentration of the ionized form and, most likely, it is in the solution in an undissociated form. At pH 5.2, extraction

of associates is practically not observed, which is apparently due to a decrease in the degree of amine protonation. The dependence of optical density on pH is shown in Fig. 1. The presence of one maximum of optical density in the specified pH ranges confirms the assumption of the formation of one complex compound.

Titanium (IV) ions are easily hydrolyzed even in acidic

environments. The degree of hydrolysis depends on the concentration of both titanium and hydrogen ions. The relative tendency of titanium to hydrolysis must be taken into account when determining it in various objects. To prevent hydrolysis, it is advisable to carry out photometric determination in acidic environments. The pH of the onset of precipitation of Ti (IV) hydroxide \sim is 0, and the pH of complete precipitation \geq is 2.

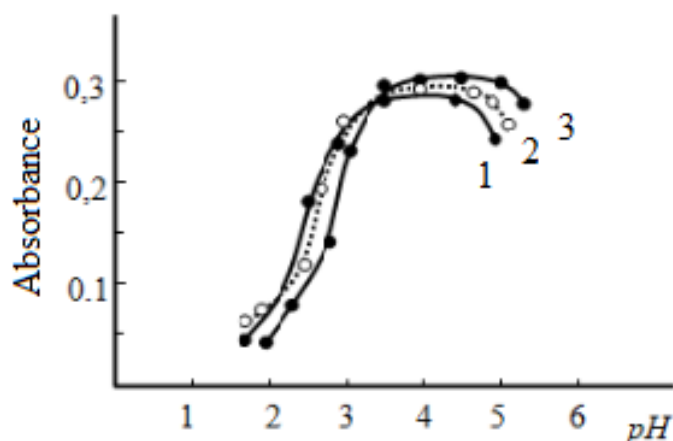


Figure 1: Dependence of the Degree of Titanium Extraction in the form of MLC on the pH of the Aqueous Phase

1. Ti (IV)-DMIPP-An, 2. Ti (IV)-DMIPP-mAn, 3. Ti (IV)-DMIPP-dAn

$C_{Ti} = 4.16 \cdot 10^{-5}$ M, $C_{DMIPP} = 1 \cdot 10^{-3}$ M, $C_{Am} = 1 \cdot 10^{-3}$ M, KFK-2, $\lambda = 440$ nm, $l = 0.5$ cm.

Titanium MLCs are formed in the presence of a large excess of complexing reagents. The optimal condition for the formation and extraction of these compounds is $(8.0 - 9.6) \times 10^{-4}$ mol/l and $(1.0 - 1.2) \times 10^{-3}$ mol/l concentration. DMIPP and Am, respectively (Fig. 2).

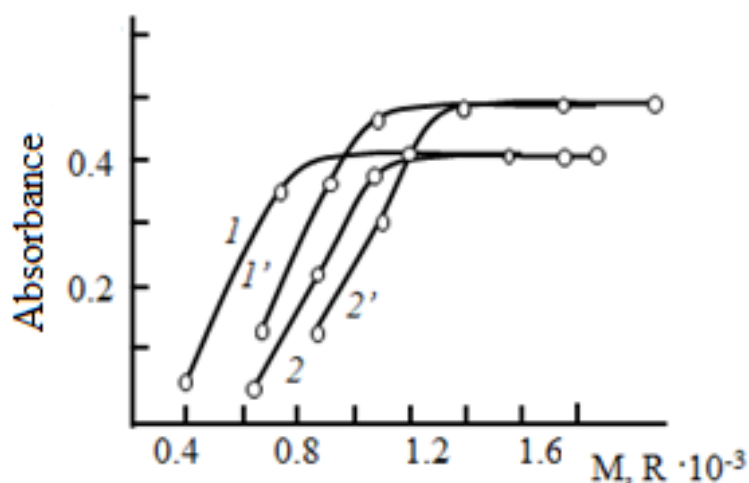


Figure 2: Effect of Concentration of DMIPP (1.1 i) and Am (2.2 i)

1,2-Ti -DMIPP-An, 1', 2' -Ti -DMIPP-mAn
 $= 1.875 \times 10^{-5}$ M; KFK-2, $\lambda = 440$ nm, $l = 0.5$ cm.

Titanium MLC with DMIPP and Am are stable in aqueous and organic solvents and do not decompose for three days, and after extraction for more than a month. The maximum optical density is achieved within 20 minutes. With weak heating (up to 30 0 C) the color develops instantly.

The maximum analytical signal during complexation of titanium with DMIPP and Am is observed at 438-446 nm (Fig. 3). DMIPP absorbs maximally at 275 nm. The bathochromic shift is 163-171 nm. The reaction contrast is high: the initial reagents are almost colorless, and the complexes are yellow. The molar absorption coefficients are $\epsilon = (2.50 - 2.68) \times 10^4$.

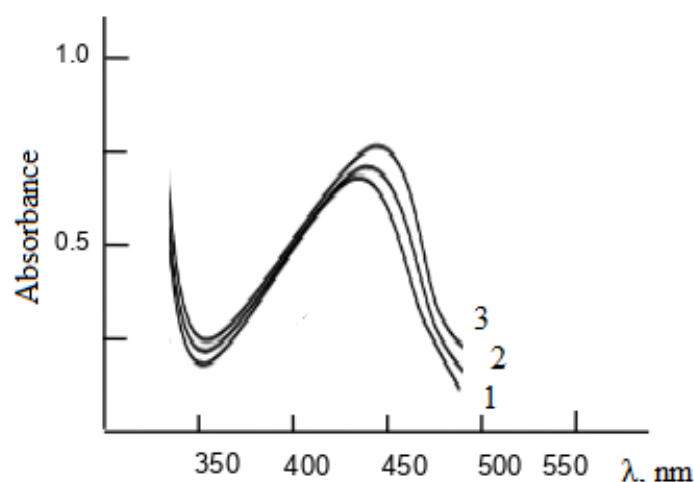


Figure 3: Light Absorption of Titanium MLC with 2,6-Dimercapto-4-Isopropylphenol and Hydrophobic Amines

Ti (IV)-DMIPP P-An (1), Ti (IV)-DMIPP-mAn (2) and Ti (IV)-DMIPP-dAn (3)

$C_{Ti} = 4.16 \cdot 10^{-5} \text{ M}$, $C_{DTBP} = 0.96 \cdot 10^{-3} \text{ M}$, $C_{Am} = 0.25-0.28 \text{ M}$; Shimadzu UV1240, $l = 1 \text{ cm}$.

The stoichiometry of the studied complexes was determined by the equilibrium shift and relative yield methods [20].

The data presented in Fig. 4 show that in the composition of the RLC there are two moles of DMIPP and Am per mole of metal. Using Nazarenko's method it was established that the complex-forming form of titanium is $Ti(OH)_2^{2+}$ [21,22]. In this case, the number of protons displaced by it from one DMIPP molecule was equal to 1.

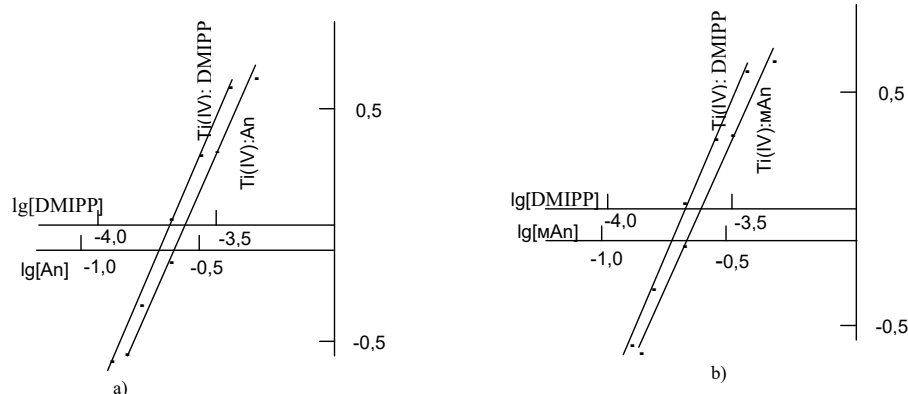


Figure 4: Determination of the Ratio of Components by the Equilibrium Shift Method for - Ti (IV)-DMIPP-An (a) and Ti (IV)-DMIPP- mAn (b)

$C_{Ti} = 4.16 \cdot 10^{-5} \text{ M}$, K_{FK}^{-2} , $\lambda = 440 \text{ nm}$, $l = 1 \text{ cm}$.

In the IR spectra of the complex, an intense absorption band appears in the region of $780-810 \text{ cm}^{-1}$ due to the stretching vibration of the group $[Ti(OH)_2]^{2+}$. The disappearance of the pronounced band at 2580 cm^{-1} observed in the spectrum of DMIPP and the appearance in the spectra of the complex of two absorption bands, one of which is shifted toward lower frequencies, indicates that one of the -SH groups is involved in the formation of the complex. The observed decrease in the intensity of the absorption band in the region of $3600-3200 \text{ cm}^{-1}$ with a maximum at 3460 cm^{-1} and the appearance of a broad band in the region of $3180-3050 \text{ cm}^{-1}$ indicate that the -OH group is involved in the formation of the coordination bond in the ionized state. The detection of absorption bands at 1380 cm^{-1} indicates the

presence of protonated aniline [18, 19].

The calculations performed showed that the MLCs in the organic phase do not polymerize and are in monomeric form ($\gamma = 1.08-1.11$) [23]. The mechanism of formation of MLC can be represented as follows. Titanium ions, when interacting with two DMIPP molecules, form a divalent anionic complex, which is extracted with two molecules of protonated Am. The composition of the extracted complexes can be represented by the formula $[Ti(OH)_2(RH)_2](AmH)_2$.

Extracts of titanium ion associates obey the basic law of light absorption at concentrations of $0.05-12 \mu\text{g}/\text{cm}^3$. The equation of the calibration graphs: $y = 0.015 + 0.011x$, $y = 0.018 + 0.0106x$ and $y = 0.014 + 0.010x$ for the complexes $[Ti(OH)_2(DMIPP)_2](AnH)_2$, $[Ti(OH)_2(DMIPP)_2](mAnH)_2$, [

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Ti(OH)₂(DMIPP)₂](dAnH)₂, respectively. The photometric detection limit of titanium in the form of ion associates was calculated using the equation [24]. The detection limit of titanium in the form of [Ti(OH)₂(DMIPP)₂](AnH)₂ is 0.015; [Ti(OH)₂(DMIPP)₂](mAnH)₂ -0.013; [Ti(OH)₂(DMIPP)₂](dAnH)₂ -0.011 µg/ml. The two-phase stability constants of the Cu(II), Hg(II) and Ti(IV) complexes were determined by the curve intersection method [20]. The concentration of the MLC was calculated using the formula

$$C_K = C_M \frac{A_x}{A_{max}}$$

Then, by specifying different values of n for the ratio of M to DMIPP equal to 1, 2, 3, the values of the stability constant of the complexes were calculated using the formula

$$\beta = \frac{C_K}{(C_M - pC_K)^p \cdot (C_{DMIPP} - qC_K)^q}$$

The calculated values of the two-phase stability constants are presented in Table 3.

Table 3 shows the main spectrophotometric characteristics of the titanium determination method.

Compound	pH	λ, nm	Contrast, nm	ε·10 ⁻⁴	lgβ	Area of subordination Beer's law, µg/ml
[Ti(OH) ₂ (DMIPP) ₂](AnH) ₂	3.3-4.5	43 8	163	2.50	9.4	0.05-8.0
[Ti(OH) ₂ (DMIPP) ₂](mAnH) ₂	3.4-4.6	44 5	170	2.65	9.7	0.05-10
[Ti(OH) ₂ (DMIPP) ₂](dAnH) ₂	3.5-4.6	44 6	171	2.68	9.8	0.1-12

Table 3: Main Spectrophotometric Characteristics of the Ti (IV) MLC with DMIPP and Am

To assess the applicability of the MLC extracts for the separation and determination of titanium, the interfering effect of foreign ions was studied. The selectivity of the spectrophotometric determination of titanium in the form of the studied MLC is presented in Table 4. It was found that large amounts of alkaline, alkaline earth elements, REE, and F⁻, Cl⁻, Br⁻, SO₃²⁻, SO₄²⁻ and C₂O₄²⁻ do not interfere with the determination of titanium. Small amounts of tartrate, chloride, sulfate, and molybdate ions also do not interfere. Nitrite, nitrate, fluoride, oxalate, and citrate ions interfere.

The interfering effect of Fe(III) was eliminated by thioglycolic acid, V(IV) by ascorbic acid, Cu(II) by thiourea, and Mo(VI) and Nb(V) by orthophosphate ion. Large amounts of Fe(III) can be masked by orthophosphoric acid. Orthophosphoric acid somewhat reduces the intensity of coloring of titanium complexes due to complexation with it. Zirconium does not form colored complexes with DMIPP, however, in its presence the absorption of titanium complexes is somewhat reduced.

Ion	Molar excess of ion	Masking reagent	Found Ti, µg	S _r
Co(II)	200		49.6	0.05
Ni(II)	200		50.3	0.04
Al(III)	230		49.8	0.04
Fe(II)	300		50.4	0.04
Mn(II)	200		50.4	0.05
Fe(III)	80	Thioglycolic acid	50.2	0.04
Cd(II)	220		30.4	0.04
Zr(IV)	70	Sodium orthophosphate	30.5	0.05
Cu(II)	80	Thiourea	50.8	0.06
V(IV)	80	potassium cyanide	49.5	0.05
W(VI)	25	Sodium orthophosphate	49.9	0.05
Mo(VI)	5	Sodium orthophosphate	50.3	0.05
Cr(III)	300		50.2	0.05
Nb(V)	75		50.2	0.06
Ta(V)	75	-	50.3	0.05

Table 4: Effect of Foreign ions on the Determination of Titanium(IV) as MLC with DM: PP and Am (50.0 mcg Ti(IV) Administered)

Table 5 presents data that allow us to compare the analytical characteristics of the methods for determining titanium (IV) with already known methods [2,3]. In terms of the main

spectrophotometric characteristics, the proposed methods are superior to the existing ones.

3.1. Analytical application

A study of the spectrophotometric parameters of the complexes allows us to conclude that these reagents are applicable for the photometric determination of titanium.

Determination of titanium in metallic aluminum. Metallic aluminum contains (%): Ti - $2.4 \cdot 10^{-2}$, Zr - $1.5 \cdot 10^{-2}$, Cu - $2.9 \cdot 10^{-2}$, Pb - $3.7 \cdot 10^{-2}$, As - $4.9 \cdot 10^{-3}$, Si - 0.19, Fe - 0.31, Zn - $6.5 \cdot 10^{-2}$, Ni - $9.1 \cdot 10^{-3}$, Mg - $2.2 \cdot 10^{-3}$, Mn - $1.3 \cdot 10^{-2}$.

A weighed sample of metallic aluminum (1 g) was dissolved in 20 ml of HCl (1:1) with heating. The solution was transferred to a 25 ml measuring flask and the volume was brought up to the mark with distilled water. An aliquot (1 ml) was placed in a separatory funnel and titanium was determined using the developed methods. The results of the determination are presented in Table 6.

Reagent	pH	SOLVENT	λ , nm	$\epsilon \times 10^{-4}$	Beer's Law Region ($\mu\text{g/ml}$)	Attitude Me:R:Am
Diantipyrylmethane	0.4-4N HCl	Water	380	1.8	0.01-1.0	
Tyrone	4.3 - 9.6		410	1.0	0.3 - 3.0	
Chromotropic acid	3.5		470	1, 2	0.1- 4.0	1:2
Dichlorochromotropic acid	2.0		490	1, 1 2	0.1- 5.0	
Tyrone + tributylamine	4.0-5.5	Chloroform	380	1.8	-	1:3:5
Chromotropic acid + tributylamine	4.5-5.0	Chloroform	425	2.7	-	1:2:4
DMIPP + mAn	3.4-4.6	Chloroform	445	2, 65	0.05-10	1:2:2
DMIPP+dAn	3.5-4.6	Chloroform	446	2.68	0.1-12	1:2:2

Table 5: Comparative Characteristics of Methods for Determining Titanium (IV)

Method	σ , % 10^{-2}	Convergence %	S 10^{-3}	$\bar{x} \pm \frac{t_p \cdot S}{\sqrt{n}}$ 10^{-2}
Tyrone + tributylamine	2.35	98	1.2	(2.35±0.13)
Chromotropic acid + tributylamine	2.38	98	1.2	(2.38±0.13)
DMIPP+An	2.46	101	0.75	(2.46±0.07)
DMIPP+mAn	2.47	99	1.05	(2.47±0.10)
DMIPP+dAn	2.38	98	0.94	(2.38±0.11)

Table 6: Results of Determination of Titanium in Metallic Aluminum (n=6, P=0.95)

Determination of titanium in waste and sea water. Four different water samples were taken for analysis: two samples of waste (Azerneftiyag Oil Refinery) and two samples of sea water (Baku, Caspian Sea). Samples of waste (0.5 and 1 l) and sea (1.5 and 2 l) water are evaporated, the resulting solid residue is dissolved in water, treated with 2 ml of HNO_3 , heated at 60-70 °C until complete distillation of HNO_3 . After this, the mixture is filtered and transferred to flasks with

a capacity of 25; 50; 100 and 200 ml, respectively. When determining titanium by the photometric method, an aliquot (1.5 ml) was placed in a separatory funnel, an optimal pH was created (pH 4), 2.5 ml of a 0.01 M DMIPP solution and 1.0-1.2 ml of Am were added, and titanium was determined using the developed methods. The results of the determination are presented in Table 7. The accuracy of the determination was established by the addition method.

Sample	Photometric method				Method of additives			
	σ , % 10^{-6}	S 10^{-7}	$\bar{x} \pm \frac{t_p \cdot S}{\sqrt{n}}$ 10^{-6}	$\bar{x} \pm \frac{t_p \cdot S}{\sqrt{n}}$ 10^{-6}	σ , % 10^{-6}	S 10^{-7}	$\bar{x} \pm \frac{t_p \cdot S}{\sqrt{n}}$ 10^{-6}	$\bar{x} \pm \frac{t_p \cdot S}{\sqrt{n}}$ 10^{-6}
<i>Waste water</i>								
1	3.25	1.78	0.053	(3.25±0.18)	3.38	1.55	0.048	(3.38±0.15)
2	3.32	1.71	0.055	(3.32±0.18)	3.35	1.49	0.052	(3.35±0.18)

Sea water								
1	3.35	1.64	0.046	(3.35±0.16)	3.46	0.10	0.031	(3.46±0.10)
2	3.39	1.53	0.047	(3.39±0.15)	3.39	0.08	0.025	(3.39±0.12)

Table 7: Results of Determination of Titanium with DMIPP and dAn in Wastewater and Seawater (n =6; P =0.95)

As can be seen from the table, the results of determining titanium in waste and sea water indicate sufficient reliability of the proposed methods.

Determination of titanium in steel. A weighed portion of the sample (1 g) was transferred to a 100 ml beaker and dissolved in 20 ml of sulfuric acid (1:4). 3 ml of perhydrol

were added, diluted with distilled water to 40 ml and boiled for 25 minutes. The contents of the beaker were transferred to a 50 ml measuring flask and brought to the mark with distilled water. An aliquot (1 ml) was placed in a separatory funnel, 1 ml of a 10% sodium thiosulfate solution was added, and titanium was determined using the developed methods. The results of the determination are presented in Table 8.

Method	,%	Convergence %	s 10 ⁻³		$\bar{x} \pm \frac{t_p \cdot S}{\sqrt{n}}$
Tyrone + tributylamine	0.092	98	2,576	0.028	0.092±0.003
DMIPP+An	0.088	99	1,958	0.029	0.088±0.004
DMIPP+mAn	0.093	102	1,729	0,025	0.091±0.002
DMIPP+dAn	0.089	101	2,245	0.031	0.089±0.002

Table 8: Results of Titanium Determination in Steel with 127a (Composition, %: Ti - 0.09; Mn - 1.58; Cr - 1.72; Ni - 0.12). n = 6; P = 0.95

4. Conclusions

- The reactions of titanium (IV) complexation with 2,6-dimercapto-4-isopropylphenol in the presence of hydrofobic amins were studied using spectrophotometric methods.
- The conditions of formation and extraction, composition, physicochemical and analytical properties of the complexes were established.
- The structure of the complexes was established using IR spectroscopy and thermal analysis methods.
- Highly sensitive, selective methods of extraction-photometric determination of copper have been developed. The methods have been applied to determine copper in food products: beans, wheat bran, gelatin, as well as in steels of various grades.

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