

Spectroscopic Investigation Complex Formation Of Titanium Using 2,6-Dithiol-4-Methylphenol And Hydrofob Amins

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Abstract: Mixed-ligand complexes of titanium(IV) with 2,6-dithiol-4-methylphenol (DTMP) and hydrofob amines(Am) have been studied by spectrophotometry. Extraction of mixed ligand complexes is maximal at pH 3.4-5.0. The optimal conditions for the formation and extraction of mixed-ligand compounds have been found and the ratios of components in the complexes have been determined. The Beer's law was applicable in the range of 0.05-2.5µg/ml. The method is free from common interferences. A procedure has been developed for extraction – spectrophotometric determination of titanium in wastewater, seawater, aluminum metal and alloys.

Keywords: Extraction-spectrophotometric method, titanium, 2,6-dithiol-4-methylphenol, hydrofob amines, mixed-ligand complexes

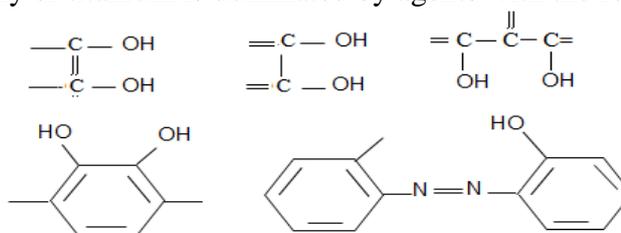
1.Introduction

Main properties of titanium, contributes to an increasing use of this metal in modern technology, -high heat resistance of both the titanium and its alloys with aluminum and other metals [1]. Metallic titanium is well known for its excellent corrosion resistance, having ability to withstand attack by dilute Sulphuric acid and hydrochloric acid or even moist chlorine. It is as strong as steel, but much lighter, yet it is heavier than aluminium and twice as strong. These properties make titanium highly resistant to the usual kinds of metal fatigue [2].

Titanium alloys are principally used for aircrafts and missiles, where light weight strength and ability to withstand extremes of temperature are important. Its capacity for joining with bone and other tissue-Osseo integration makes it suitable for medical applications, such as total replacement of arthritis hips, knee joints, facial treatment and dental implants [3].

Titanium belongs to the elements to determine which many methods have been developed. The most widely used methods with Tyrone, chromotropic acid and dianthipyryl methane. The most sensitive methods include thiocyanate method (with extraction) and methods with application of fluorone [4, 5]. Reagents containing hydroxy - and carboxy, or two hydroxy groups in *ortho*-position to each other, interact mainly with titanium in weakly acidic solutions to form a colored complex compounds [6].

For the determination of titanium(IV) in micro levels, there are several frequently adopted methods using analytical techniques, such as AAS, ICP-AES, ICP-MS, x-ray fluorescence spectroscopy, spectrophotometry and such other techniques. Among these, spectrophotometric methods are preferred because they are cheaper and easier to handle, with comparable sensitivity. In analytical chemistry of titanium is dominated by agents with the following groups [5, 6]:



For spectrophotometric determination of iron in various samples suggested salicylhydroxamic acid [7], 3,4-dihydroxybenzaldehydeisonicotinoylhydrazine [8], 2,4-dihydroxybenzaldehydeisonicotinoylhydrazine [9], pyridoxal salicyloylhydrazine [10], 4-nitrocatechol and the tetrazo-

lium salts tetrazol violet and idonitrotetrazolium chloride [11], 2,4-Dihydroxy acetophenone isonicotinoylhydrazone [12], 3- hydroxy-2-(3'-methyl-2'-thienyl)-4-oxo-4H-1-benzopyran[13].

Dimercaptophenolate complexes of *d*-elements (Mo, V, Co, Cu) are insoluble in chloroform, while mixed-ligand complexes with hydrophobic amines and aminophenols easily dissolve in various organic solvents [14, 15, 16, 17].

The present study is concerned with the investigation of titanium (IV) interaction with 2,6-dithiol-4-methylphenol (DTMP), resulting in the formation of colored complexes insoluble in nonpolar solvents. When hydrophobic amines (Am) were introduced into the system, the extraction of these compounds into the organic phase as a mixed-ligand complex (MLC) was observed. Among hydrophobic amines Aniline (An) and *N*-methylaniline (mAn) were used. Based on these data, new selective and highly sensitive procedures were developed for the extraction-spectrophotometric determination of trace titanium in alloys, tap water and oil biological samples.

2. EXPERIMENTAL

2.1. Instrumentation

The absorbance of colored solutions was measured at $20 \pm 1^\circ\text{C}$ using a KFK-2 photo-electrocolorimeter and Shimadzu UV-visible spectrophotometer (Model UV-1240) in cells 0.5 and 1.0 cm in thickness, respectively. The equilibrium value of the pH of aqueous phase was measured using a I-120.2 potentiometer with a glass electrode. IR - spectra were recorded on a spectrophotometer specord M 80.

2.2. Reagents and solutions

Stock solutions (2.08×10^{-2} M) Ti (IV) was prepared as follows: 0.835 g of pure TiO_2 calcined at a temperature of 900°C alloyed with 8 g of $\text{K}_2\text{S}_2\text{O}_7$ in a quartz crucible. The clear melt is cooled and dissolved in 150 ml of hot H_2SO_4 (1: 2). The solution after cooling was diluted with sulfuric acid (1: 5) in a volumetric flask of 500 ml [4] and standardized by gravimetrically [18]. Lower concentrations of the metal ion are obtained by suitable dilution of the stock solution.

Were used a 0.01 M DTMP and Am solution in chloroform. An optimum acidity was created by means of 1 M HCl or an sodium acetate acetic acid buffer solution. Chloroform was purified by washing with conc. H_2SO_4 and shaking with distilled water followed by washing with a 5% solution of NaOH.

2.3. Procedure

2.3.1. General procedure for the determination of titanium (IV)

Required aliquots of solution containing different amounts (0.03-3.0 $\mu\text{g}/\text{ml}$) of titanium (IV) were transferred into were calibrated test tubes with ground-glass stoppers (the volume of the organic phase was 5mL). 2.5 mL portion of a 0.01 M solution of DTMP, and a 2.5 mL portion of a 0.01M solution of Am were added and the required value of pH was adjusted by adding 4.0 mL of sodium acetate acetic acid buffer (pH 4.0). The volume of the aqueous phase was increased to 20 mL with distilled water. In 10 min after the complete separation of the phases, the organic phase was separated from the aqueous phase and the absorbance of the extracts was measured on KFK-2 at room temperature and 440 nm ($l=0.5\text{cm}$).

2.3.2. Determination of titanium (IV) in wastewater and seawater

For the analysis, four different samples of water were taken: two samples of the wastewater (Azerneftiyag refineries) and two samples of seawater (Baku, Caspian Sea). Samples of effluent (0.5 and 1 liter) and marine (1.5 and 2 liters) of water evaporated, the solid residue is dissolved in water, treated with 2 ml of HNO_3 , was heated at $60-70^\circ\text{C}$ until complete distillation of HNO_3 . The mixture was filtered and transferred to 25; 50; 100 and 200 ml flasks respectively. When determining titanium photometrically aliquot (15 ml) was placed in a

separatory funnel create optimum pH (pH = 4) was added 2.5 ml of 0.01 M solution DTMP, 1.0-1.2 ml 0.01 M solution Am and titanium determined by developed procedure.

2.3.3. Determination of titanium in the metallic aluminum

Weigh aluminum metal (1 g) was dissolved with heating in 20 ml HCl (1: 1). The solution was transferred into a volumetric flask and adjusted to 25 ml volume with distilled water to the mark. An aliquot (1 ml) was placed in a separatory funnel and determined titanium by developed procedure.

2.3.4. Preparation of alloy sample solutions

Accurately weighted amount of the alloy sample was dissolved in a mixture of 2 ml of concentrated hydrochloric acid and 10 ml of concentrated nitric acid. The solution was evaporated to a small volume, 1:1 sulphuric acid was added and the solution was then evaporated to dryness. The residue was dissolved in 15 ml of distilled water and filtered. The filtrate was transferred into a 100 ml standard flask and diluted to the mark with distilled water. This serves as stock solution. The stock solution was appropriately diluted to obtain the metal ion solution in the required concentration range.

3. RESULTS AND DISCUSSION

The present study is concerned with the investigation of Ti(IV) interaction with DTMP, resulting in the formation of colored complexes insoluble in nonpolar solvents. Experiments on electromigration in a U-shaped tube and on sorption on EDE-10P (EDE- ethylenediamine, epichlorohydrin; 10- serial number of the brand; P- means that the matrix has a macroporous structure) anion exchangers have demonstrated the anionic nature of singleligand complexes, in the electromigration study of the complexes, it was found that the blue dithiophenolate complexes of titanium(IV) moved to the cathode. When the sign of the charge of the single-ligand complexes was determined by ion chromatography, the EDE-10P anion exchanger completely absorbed the colored component of the solution. When hydrophob amins (Am) were introduced into the system, the extraction of these compounds into the organic phase as a mixed-ligand complex (MLC) was observed.

DTMP are weak tribasic acid (H_3R) and depending on the pH of the medium may be in molecular and two anionic forms. Solutions of DTMP and Am in chloroform (0.01M) were used. DTMP were synthesized according to the procedure [19] Structure of ligand was confirmed by using NMR and IR spectra[20, 21,22].

IR (KBr): 3460 cm^{-1} ν (OH), 3050 cm^{-1} ν (CH), 2570 cm^{-1} ν (SH), 2962 и 2872 cm^{-1} , ν ($-CH_3$), 1555 cm^{-1} δ (C_6H_5), 1390 cm^{-1} δ_{as} ($-CH_3$).

1H NMR (300,18 MHz, C_6D_6): δ 5.24 (s, 1H- OH), δ 3.32(s, 2H - 2SH), δ 7.11 (s, 2H Ar-H), δ 2.38 (s, 3H $-CH_3$).

3.1. Effect of pH

The effect of pH on the intensity of the color reaction is shown in the Fig. 3. The absorbance was found to be maximum in the pH range 3.3-4.5. Hence further analytical investigations were carried out in media of pH 4. With further increase in the acidity of the aqueous phase, the recovery of titanium(IV) decreases. This is because with increasing acidity, the concentration of the anionic reactive form of titanium(IV) decreases. At $pH \geq 6$, the extraction of the complex is practically not observed, which is probably because a decrease in the degree of protonation of Am. $CHCl_3$, CCl_4 , $C_2H_2Cl_2$, C_6H_6 , $C_6H_5CH_3$, isopentanol, *n*-hexanol, and their mixtures were tested as extractants. $CHCl_3$, $C_2H_2Cl_2$, chlorobenzene, and were the best diluents. All the further investigations were carried out with chloroform. In a single extraction with chloroform, 97.6-97.9 % of titanium (IV) is extracted in the form of mixedligand complex. The concentration

of titanium(IV) in the organic phase was determined photometrically by using chromotropic acid [4] after reextraction, and in the aqueous phase, its concentration was found by the difference.

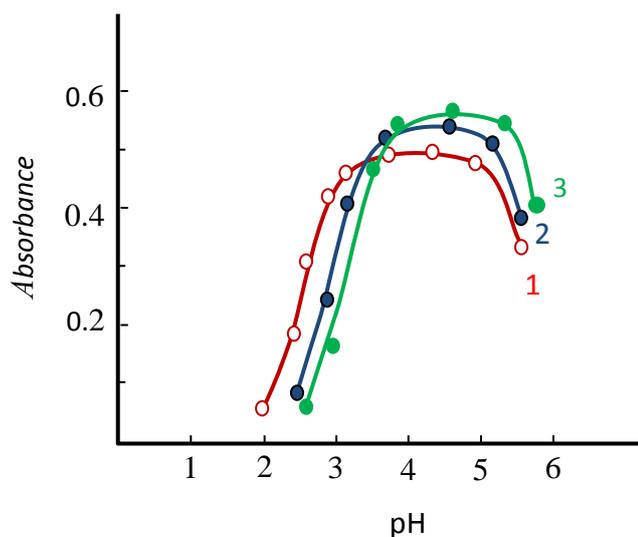


Fig.1. Absorbance of mixed-ligand complexes as a function of the pH of the aqueous phase.

1. Ti(IV)-DTMP-An; 2. Ti(IV)-DTMP-mAn, 3. Ti(IV)-DTMP-mAn

$C_{Ti}=4.16 \times 10^{-5} M$, $C_{DTMP}=1.0 \times 10^{-3} M$, $C_{Am}=1.2 \times 10^{-3} M$, KFK-2, 440 nm, $l=0.5$ cm.

3.2. Electronic absorption spectra

The proposed method involved the formation of a brownish blue-green color between titanium(IV) and DTMP in a medium of pH 4 (fig.2). The figure revealed that Ti(IV)-DTMP-Am complex has maximum absorbance at 432-435 nm. Neither the metal ion nor the reagent has appreciable absorbance at specified wavelengths. Hence further studies were carried out at 440 nm. The molar coefficient of light absorption is $(2.32-2.48) \cdot 10^4 l \cdot \text{mol}^{-1} \text{cm}^{-1}$.

The color reaction was instantaneous and the absorbance of the complex solution was found to remain constant for at least five hours.

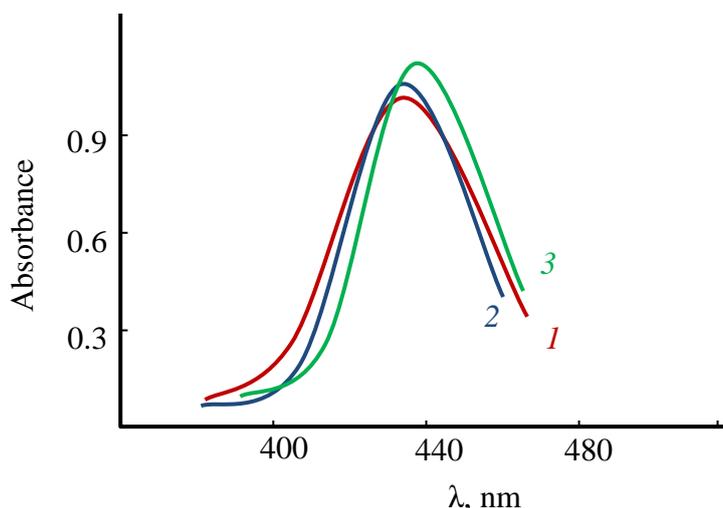


Fig.2. Absorption of mixed-ligand complexes

(1) Ti(IV)- DTMP-An, (2) Ti(IV)-DTMP-mAn

$C_{Ti}=4.16 \times 10^{-5} M$, $C_{DTMP}=1.0 \times 10^{-3} M$, $C_{Am}=1.2 \times 10^{-3} M$, SF-26, $l=1$ cm.

3.3. Effect of reagent concentration and incubation time

The studies on effect of various concentrations of the reagent on the color reaction reveal that, a reagent excess of 5-10 fold was required for the Ti(IV)-DTMP-Am color reaction. Ho-

wever it was found that the presence of excess of the reagent solution does not alter the absorbance of the color reaction. For the formation of mixed-ligand complex Ti(IV)– DTMP – Am, the concentration of 1.0×10^{-3} M of DTMP and 1.2×10^{-3} M of Am in the solution is required. Unlike single-ligand complexes, mixed-ligand complexes of titanium(IV) with DTMP and Am were stable in aqueous and organic solvents and did not decompose for two days, or over a month after extraction. The required duration of the phase contact was 10 min.

3.4. Stoichiometry of the complexes and the mechanism of complexation

The ratio of components in the complex corresponds to Ti(IV) : DTMP : Am = 1 : 2 : 2; it was determined by the methods of straight line, equilibrium shift, and the relative yield [23] (Fig. 3). It was found using the Nazarenko method that Ti(IV) in the complexes was present in the form of $\text{Ti}(\text{OH})_2^{2+}$. The number of protons replaced by vanadium in one DTMP molecule appeared to be one [24, 25].

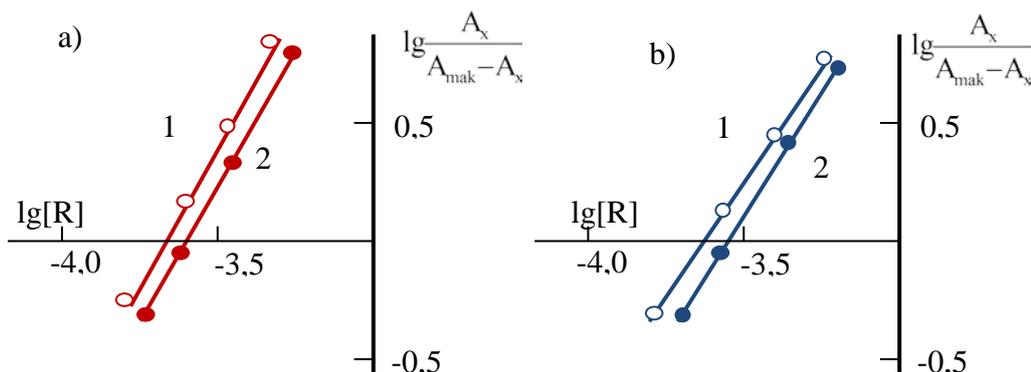


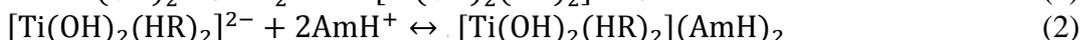
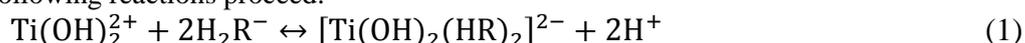
Fig. 3. Determination of the ratio of components by the equilibrium shift method for (a) Ti(IV)- DTMP-An and (b) Ti(IV)-DTMP-mAn.

1, Ti : DTMP; 2, Ti : Am.

$C_{\text{Ti}}=4.16 \times 10^{-5}$ M, $C_{\text{DTMP}} = 1.0 \times 10^{-3}$ M, $C_{\text{Am}}=1.2 \times 10^{-3}$ M, SF-26, $l=440$ nm, $l=1$ cm

Constant of stability of complexes are determined by method of crossing of curves [23].

Given the found component ratio in the complex and an ionic state of titanium, it was assumed that upon complexation, the following reactions proceed:



From Eqs. (1) and (2), one can judge the reaction mechanism: titanium(IV) is reduced by DTMP in a hydrochloric acid medium to titanium(IV), and the latter in the form of a chloride complex cation interacts with excess DTMP. The resulting anionic complex $[\text{Ti}(\text{OH})_2(\text{HR})_2]^{2-}$ is reacted with Am, which the acidic solution is in the protonated state (AmH^+). Using Eq. (2), the equilibrium constant can be calculated by equation

$$\lg K_e = \lg D - 2\lg[\text{AmH}^+]$$

The data for calculating $\lg K_e$ of the complex are given in Table 1.

Calculation of extent of polymerization of complexes was carried out on the equation [26]. The made calculations showed that MLC in an organic phase won't be polymerized and are in a monomeric form ($\gamma=1.08-1.11$).

The disappearance of a distinct strip at 2580 cm^{-1} , observed in ranges DTMP and emergence spectrum of complexes of two strips of absorption one of which is displaced towards smaller frequencies, says that one of the sulfhydryl groups participates in formation of a complex. The disappearance of intensity of a strip of absorption in area $3200-3600 \text{ cm}^{-1}$ with a maximum at 3450 cm^{-1} , shows that the hydroxyl group takes part in formation of communication in

the ionized state. Detection of strips of absorption at 2380 cm^{-1} indicates availability of the protonated aniline [21, 22]

Structure extractable complexes can be represented as in Figure 4.

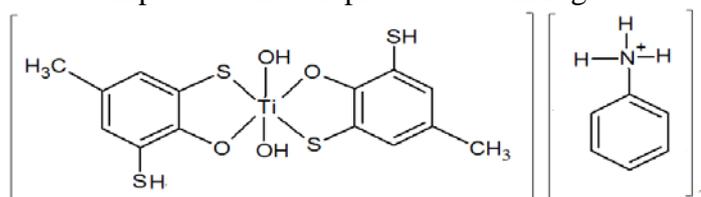


Fig. 4. Structure of complex Ti(IV)-DTMP-An

3.5. Effect of diverse ions

The effect of foreign ions on complexation was studied by taking 1.0 mL of Ti(IV) solution, 1.0 mL of required concentration of the foreign ion solution, 4.0 mL of sodium acetateacetic acid buffer (pH 4.0), 2.5 mL of DTMP and 2.5 mL An solution in a 25.0 mL standard flask. The total volume of the solution was brought to 25.0 mL with double distilled water. The experiment was repeated by changing the concentration of the diverse ion. The absorbances were measured at 440 nm.

The selectivity for the spectrophotometric determination of titanium in the form of the complex described above is presented in Table 1. It is determined that large amounts of alkali and alkaline-earth metals and REE do not interfere with the determination of titanium. The interference of Fe (III) was eliminated by orthophosphat acid: Cu(II), Cr(VI), and Mn(VII) were masked by thiourea. Ions of Mo(VI), W(VI), V(IV), Nb(V), and Ta(V) form with DTMP and Am colored compounds and interfere with the determination of titanium. However, these elements form complexes in more acidic medium. Tartrate masks the milligram quantities of Ta, W and Mo. Zr fluorides should mask, and copper-thiourea.

The interference of Cu(II) and Mo(VI) could be suppressed by using 1.0 mL of 2% EDTA. The interference of Pd(II) could be suppressed by using 1.0 mL of 0.2% phosphate. The interference of V(V) and Cr(VI) could be suppressed by using 1.0 mL of 0.2% thiocyanate.

In conclusion the analytical parameters pertaining to the proposed method are given in the Table 2. These results reveal that various cations and anions can be tolerated at satisfactory levels.

Table1. Influence of interfering ions on the determination of titanium (IV) as MLC with DTMP and mAn(50,0 mg Ti(IV) added)

Ion	Molar excess of the ion	Masking agent	Found Ti, μkg	RSD (%)
Co(II)	220		50.0	3
Ni(II)	220		50.2	3
Al(III)	220		49.8	4
Fe(II)	80		49.6	4
Mn(II)	200		50.4	5
Hg	25		49.7	3
Fe(III)	80	Sodium orthophosphate	50.2	4
Cd(II)	210		50.2	3
Zr(IV)	65	Sodium orthophosphate	50.5	5
Cu(II)	80	Thiourea	50.8	5
V(IV)	80	Potassium cyanide	49.6	5
W(VI)	25	Sodium orthophosphate	49.8	4
Mo(VI)	5	Sodium orthophosphate	50.3	5
Cr(III)	350		50.2	2

Nb(V)	75		50.2	6
Ta(V)	75	-	50.2	5
Zn(II)		Sodium pyrophosphate	49.8	5
Salicylic acid	55		49.3	5
Urea	60		50.4	4
Thiourea	1000		49.5	3
Citric acid	30		49.8	4
EDTA	500		49.8	5
Ascorbic acid	50		50.2	2
Oxalate	500		50.2	6
Phosphate	500		49.7	4
Thiocyanate	500		49.8	3
Iodide	550		50.5	2
Fluoride	160			

Table 2. Physico-chemical and analytical characteristics of Ti(IV)-DTMP-Am complex

Characteristics	Value		
	An	mAn	dAn
Color	yellow	yellow	yellow
λ_{\max}	432	432	435
pH range	2.3-6.4	2.5-6.5	2.5-6.5
Optimum pH range	3.4-4.7	3.3-4.9	3.4-5.0
Mole of reagent required per mole of metal ion for full colour development	5 -10(folds)	5-10(folds)	5-10(folds)
Molar absorptivity (L.mol ⁻¹ cm ⁻¹)	2.32×10^4	2.41×10^4	2.48×10^4
Sandal's sensitivity (ng/cm ²)	2.07	1.99	1.93
Beer's law validity range ($\mu\text{g/ml}$)	0.05-2.4	0.05-2.5	0.05-2.5
The equation of calibration curves	$0.028+0.228x$	$0.025+0.235x$	$0.032+0.248x$
Regression coefficient	0.985	0.979	0.981
Composition of complex (Ti: DTMP:Am)	1:2:2	1:2:2	
Stability constant of the complex	10.27	10.36	10.43
$\lg K_e$	5.62	5.65	5.73
R (%)	97.6	97.7	97.9

The proposed method has significant advantage over the other spectrophotometric methods in terms of simplicity and sensitivity. This proposed method has good precision and accuracy (Table 3).

Table 3. Comparative characteristics of the procedures for determining vanadium

Reagent	pH	λ , nm	$\epsilon \cdot 10^{-4}$	Beer's law range	Reference
3,4-Dihydroxybenzaldehyde isonicotinoyl-hydrazone	3.5	370	1.49	0.5-4.25	[8]
2,4-dihydroxybenzaldehyde isonicotinoyl-hydrazone	1.0-7.0	430	1.35	0.09-2.15	[9]
Pyridoxal salicyloylhydrazone	0.9-2.5	390	-	-	[10]
N'-(2-hydroxybenzylidene)-3-oxobutane-hydrazide	2.0	500	1.68	1.757 - 17.57	[27]
Chromotropic acid	3.5	470	1,2	0,1-4,0	[4,5]
Chromotropic acid + tributylamine	4.5-5.0	425	2.7	-	[4,5]

Tyrone + tributylamine	4,0-5,5	380	1,8	-	[4,5]
DTMP+An	3.4-4.7	432	2.32	0.05-2.4	
DTMP+mAn	3.3-4.9	432	2.41	0.05-2.5	
DTMP+dAn	3.4-5.0	435	2.48	0.05-2.5	

3.6. Effect of titanium (IV) concentration

The adherence to Beer's law was studied by measuring the absorbance value of the series of solutions containing different concentrations of the metal ion. A linear calibration graph drawn between absorbance and the metal ion concentration indicates that Ti(IV) may be determined in the range 0.05-2.5 $\mu\text{g/ml}$ [28]. The pertaining calibration graph is shown in the Fig. 5

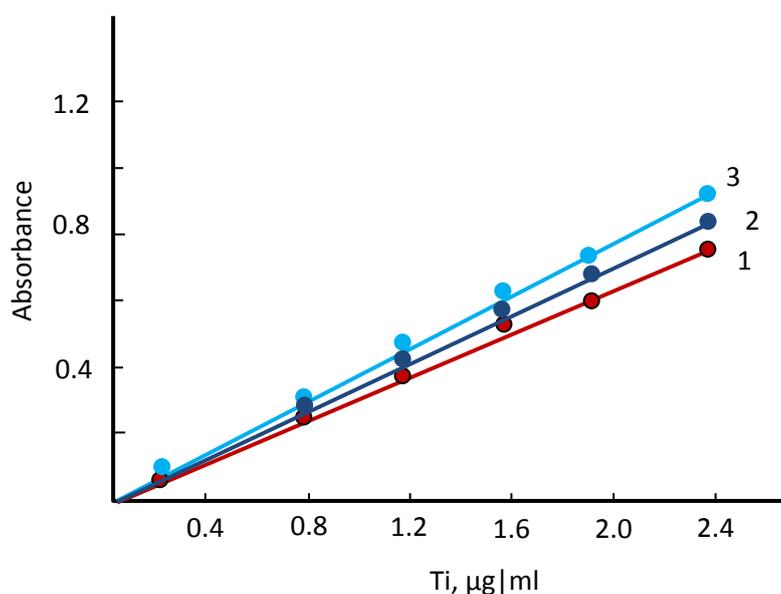


Fig. 5. Analytical determination of Ti (IV)

$C_{\text{DTMP}} = 1.0 \times 10^{-3} \text{ M}$; $C_{\text{Am}} = 1.2 \times 10^{-3} \text{ M}$; $\text{pH} = 4$; $\lambda = 440 \text{ nm}$, $l = 0.5 \text{ cm}$.

3.7. Analytical Applications

The proposed method under the already established optimum conditions was applied for the de-termination of Ti(IV) in wastewater, seawater, aluminum metal and alloys. The proposed procedures for determining titanium in soils were verified by Chromotropic acide methods [8]. The results presented in Table 4-6 indicate the successful applicability of the proposed method to real sample analysis.

Table 4. The results of the titanium in wastewater and seawater ($n = 6$, $p = 0.95$)

Sample	Photometric method				Additive method			
	$\bar{x}, \% \cdot 10^{-6}$	$S \cdot 10^{-7}$	s_r	$\bar{X} \pm \frac{t_p \cdot S}{\sqrt{n}} \cdot 10^{-6}$	$\bar{x}, \% \cdot 10^{-6}$	$S \cdot 10^{-7}$	s_r	$\bar{X} \pm \frac{t_p \cdot S}{\sqrt{n}} \cdot 10^{-6}$
wastewater								
1	3,28	1,74	0,053	(3,28±0,18)	3,33	1,49	0,045	(3,33±0,15)
2	3,30	1,68	0,051	(3,30±0,18)	3,35	1,40	0,042	(3,35±0,15)
seawater								
1	3,35	1,54	0,046	(3,35±0,16)	3,44	0,10	0,030	(3,44±0,10)
2	3,36	1,41	0,042	(3,36±0,15)	3,42	0,08	0,025	(3,42±0,09)

Table 5. Determination results of titanium in standard samples (n = 6, p = 0.95)

Standard samples	Метод	$\bar{x}, \%$	$S \cdot 10^{-3}$	S_r	$\bar{X} \pm \frac{t_p \cdot S}{\sqrt{n}}$
Steel c 127 ^a	Tyrone + tributylamine	0.092	2.576	0.028	0.092±0.003
	DTMP+An	0.089	1.958	0.022	0.089±0.002
	DTMP+mAn	0.091	1.729	0.019	0.091±0.002
	DTMP+dAn	0.089	2.225	0.025	0.089±0.002
СП-1	Tyrone + tributylamine	0.474	0.018	0.038	0.474±0.020
	DTMP+An	0.483	0.015	0.031	0.483±0.016
	DTMP+mAn	0.442	0.011	0.025	0.442±0.012
	DTMP+dAn	0.450	0.015	0.034	0.450±0.016
Aluminum metal	Tyrone + tributylamine	2.36	1.2	0.053	(2.36±0.13)
	Chromotropic acid + tributylamine	2.38	1.2	0.055	(2.38±0.13)
	DTMP+An	2.45	0.75	0.034	(2.45±0.08)
	DTMP+mAn	2.44	1.00	0.048	(2.44±0.11)
	DTMP+dAn	2.36	0.94	0.043	(2.36±0.10)

4. CONCLUSION

The present method using 2,6-dithiol-4-methylphenole (DTMP) as spectrophotometric reagent for the determination of titanium(IV) in acidic medium is sensitive and simple. The determination of titanium (IV) using DTMP is not laborious and there is no need of heating or extraction of the components.

Mixed-ligand complexes of titanium(IV) with dithiolphenole and hydrofob amins have been studied by spectrophotometry. Extraction of mixed ligand complexes is maximal at pH 3.4-5.0. The optimal conditions for the formation and extraction of mixed-ligand compounds have been found. The molar ratio of the reacting Ti(IV), DTMP and Am species is 1:2:2. The general formula of the ternary complexes is $[Ti(OH)_2(DTMP)_2](AmH)_2$. They can be regarded as ion-associates between doubly charged anionic chelates $[Ti(OH)_2(DTMP)_2]^{2-}$ and protonated Am species.

A procedure has been developed for extraction-spectrophotometric determination of titanium in wastewater, seawater, aluminum metal and alloys.

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