International Journal of Chemical Studies

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Extraction-photometric determination of iron in fruit, berries and in natural waters

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Abstract
To study the formation of a mixed ligand complex of iron with 2-hydroxy-5-halogenthiophenol and hydrophobic amines. The effect of reagent concentration, time and temperature on the formation of ternary complexes and the determination of their stoichiometry by various methods. It was found that the extracted compound is formed in a ratio of 1:2:2. The complex includes the ions Fe^{3+} and $Fe(OH)^{2+}$. The molar absorption coefficient of the complexes is $(3.0-4.5)\times10^4$ (λ = 545-595 nm). The method was used to determine traces of iron in fruits and natural waters.

Keywords: iron (III), mixed-ligand complex, complexation, extraction

1. Introduction

Iron - the most important element of human life. Iron deficiency leads to diseases of the hematopoietic system and malfunctions in children. However, with a higher content, it is toxic. Thus, when using more than 200 mg of iron per day, hyperechoic syrosis occurs. Therefore, analytical control of the iron content in the environment, especially in natural waters and fruits, should be carried out with sufficiently reliable methods. Iron belongs to the transition elements and forms a very strong coordination from any donor atoms of the ligands. Reagents containing OH groups and nitrogen donor atoms are considered most suitable for the determination of iron (III) [1, 2]. The methods of photometric determination of iron (III) in the form of mixed-ligand complexes (RFA) with this reagent in the presence of third components of different classes possess high sensitivity [3-8].

Selective for iron (III) are reagents containing the OH group. The reaction of diphenols Fe (III) is more sensitive than reagents containing one OH group [6]. When replacing a single OH group with an SH group, the selectivity decreases, since elements interact with SH-containing reagents with sulfur affinity, but rather increase the sensitivity [1], a. Thiodithiophenols, as analytical reagents, are constantly in the center of attention of researchers [9-14]. This is due to the large range of these compounds, as well as the possibility of obtaining new substances based on well-studied thiophenols.

The purpose of this work is the development of highly selective methods of photometric determination of iron (III) in the environment, in particular in natural waters (Kura river) and fruits (white and red cherries and strawberries) using hydroxyhalogenthiophenol (H_2R) - 2-hydroxy-5-chlorothiophenol (HCTP), 2-hydroxy-5-bromothiophenol (HBTP) and 2-hydroxy-5-iodothiophenol (HITP) and the hydrophobic amine (Am) -1,10-phenanthroline (Phen) α, α'-dipyridyl (Dip), diphenylguanidine (DPG), *o, m, p*-toluidine (o-Tol) (*m*-Tol) (*p*-Tol), *o. m, p*-xylidine (*o*-Xyl) (*m*-Xyl), (*p*-Xyl).

2. Experimental
2.1 Apparatus and Reagents

Apparatus. Spectrophotometric studies of the colored solutions were carried out on KFK-2 and SF-26 with an absorbing layer thickness of 0.5 = 0.5 and 1.0 cm, respectively. The pH measurement of the aqueous phase was carried out on I-120.2 using a glass electrode.

Reagents. A solution of iron (III) (0.1 mg/ml) was prepared by dissolving $FeCl_3 \times H_2O$, as described in [15]. Used 0.01 M solutions of H_2R and Am in chloroform. The purity of the reagents was monitored by chromatography and melting point. Constant concentration of hydrogen ions in solutions was maintained using ammonium acetate buffer (pH 3-11), constant ionic strength μ = 0.1 using KCl.

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2.2 H₂R dissociation constants

H_2R - contains – OH and SH group and can dissociate during complexation in two stages K_1 and K_2 (pK$_1$ and pK$_2$). To determine the first and second dissociation constants of hydroxy halogen thiophenol by pH titration [16], taken at $20 \pm 5°C$ 0.1, H_2R M solution, 1 ml 1 N HClO$_4$, ionic strength $\mu = 0.1$, are created using a 2 M solution KCl 1 - 2 ml). The final volume of the mixture is titrated to 50 ml. Titration was performed with 1 M NaOH solution. Calculation of K_1 and K_2 (pK$_1$ and pK$_2$) obtained from the results of titration of the dissociation of H_2R [16].

$$pK_1 = pH + \lg \frac{[HR]}{[R^-]} \; ; \quad pK_2 = pH + \lg \frac{[HR]+[OH^-]}{[R^-]-[OH^-]}$$

Hydroxy Halophenol are a diacid and depending on the acidity of the medium they can be in molecular (H_2R) and anionic (HR^- and R^{2-}) forms:

H_2R \quad HR^- \quad R^{2-}
X= -Cl, -Br, - J
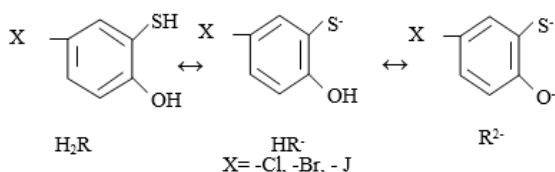
Distribution of different forms of the reactant depending on the pH is shown in Fig. 1. It can be seen that at pH <2 reagent is generally in the molecular form H_2R.
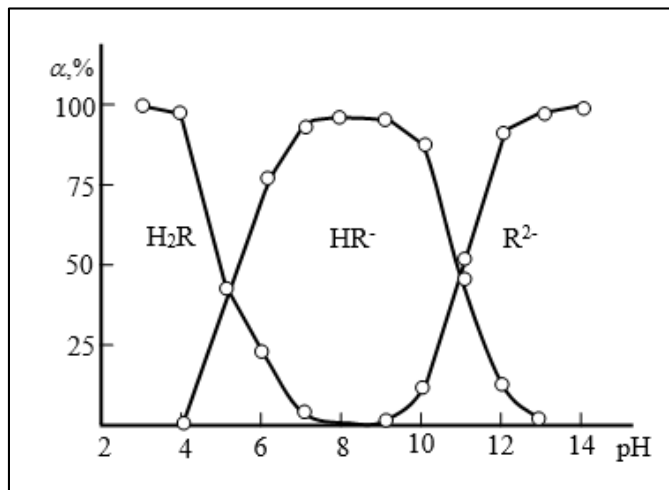

Fig 1: The distribution of HCTP in different forms depending on pH

Constants obtained for solutions with different ionic strength, are shown in Table 1.

Table 1: The ionization constants (pKa) H_2R depending on the ionic strength of the solution. ($C_{H2R} = 0.1M$, t = 25 ± 0.5°C, n = 6, P = 0.95.)

Ionic strength (μ)	$pK \pm \frac{t_p S}{\sqrt{n}}$					
	HCTP		**HBTP**		**HITP**	
	pK₁	**pK₂**	**pK₁**	**pK₂**	**pK₁**	**pK₂**
0.1	5.10±0.04	10.6±0.03	5.05±0.06	10.40±0.02	5.0±0.03	10.2±0.07
0.2	5.03±0.06	10.55±0.04	4.96±0.06	10.34±0.07	4.94±0.04	10.13±0.04
0.3	4.97±0.07	10.51±0.06	4.89±0.07	10.30±0.04	4.89±0.07	10.08±0.05
0.4	4.93±0.05	10.47±0.04	4.84±0.04	10.27±0.06	4.86±0.05	10.04±0.03
0.5	4.88±0.06	10.44±0.05	4.79±0.05	10.24±0.05	4.82±0.05	10.0±0.06
0.6	4.85±0.06	10.42±0.07	4.75±0.07	10.21±0.03	4.79±0.06	9.97±0.07
0.7	4.81±0.03	10.39±0.05	4.70±0.05	10.18±0.05	4.76±0.04	9.94±0.06
0.8	4.77±0.06	10.37±0.04	4.67±0.06	10.16±0.07	4.74±0.05	9.91±0.05
0.9	4.75±0.07	10.35±0.6	4.63±0.06	10.13±0.04	4.71±0.06	9.88±0.05
1.0	4.280.05	10.33±0.03	4.26±0.07	10.11±0.06	4.68±0.05	9.85±0.04

The dependence of the ionization constants (pK$_a$) H_2R the solution ionic strength pK$_n$ = f(μ) (Fig. 2) in the range of μ = 0 - 1 linear and described by the equations:
HCTP: pK$_1$ = 5.2762 – 0.5506√μ; pK$_2$ = 10.7289 – 0.4028√μ.
HBTP: pK$_1$ = 5.2643 – 0.6697√μ; pK$_2$ = 10.5341 – 0.4191√μ.
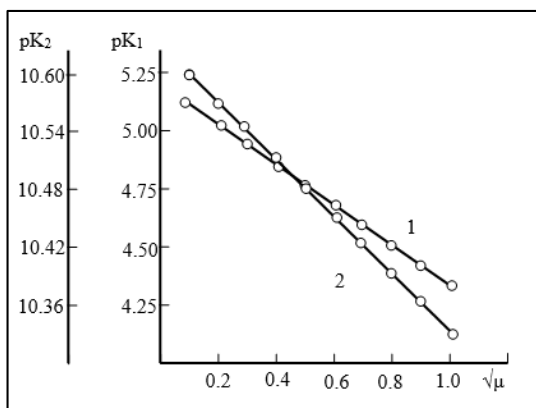HITP: pK$_1$ = 5.1483 – 0.4634√μ; pK$_2$ = 10.3621– 0.5066√μ.

Fig 2: Dependence pK$_1$ (1) and pK$_2$ (2) of the ionic strength of the solution. C_{HCTF} = 0,1M.

2.3 General Procedure for the Determination of Fe (III)

In the flask, 0.1-1.0 ml were injected at intervals of 0.2 ml of the initial solution of Fe (III) (0.1 mg / ml), 2.0-2.5 ml of a 0.01 M H_2R solution and 1.0- 1.5 ml of 0.01 M Am, 1.0-2.0 ml of CHCl$_3$ and 4 ml of buffer solution are diluted to the mark with water. 10 minutes after the separation phase was complete, the organic layer was separated and its optical density was measured at room temperature KFK-2 at λ = 540 (590) nm (ℓ= 0.5 cm).

2.4 Charge of the complexes

The charge of the Fe (III)-R binary complexes was determined by electromigration and ion-exchange. Experiments on electromigration in a U-shaped tube and on sorption on EDE-10P anion exchanger demonstrated the anionic nature of the complexes. Under the experimental

conditions, these red binary complexes were insoluble in nonpolar organic solvents. However, when Ams were introduced the formation of electroneutral chloroform extractable mixed ligand complexes (MLC) was observed.

2.5 Determination of iron in fruits and berries

After drying, a portion of a sample of fruit weighing 200 g is placed in a graphite cup, burned in a muffle furnace at 550-750 ºC until complete decomposition of organic substances. The resulting ash is dissolved in a mixture of 15 ml of HCl and 5 ml of HNO_3 in a glassy carbon dish and treated three times with 4-5 ml of HCl at 60-70ºC until the nitrogen oxides are completely distilled off. Next, the mixture is dissolved in distilled water, filtered in a flask with a capacity of 100 ml and diluted to the mark. An aliquot of the solution (10.0 ml) is transferred to a 25 ml volumetric flask, with 2.0-2.5 ml of a 0.01 M H_2R solution, 1.2-1.5 ml of 0.01 M Dip (Phen) and 1.8 -1.0 ml of $CHCl_3$. The required pH was adjusted with ammonium acetate buffer and the volume was adjusted to the mark with distilled water. After 5-10 minutes after complete separation of the phases, the organic layer was separated and its optical density was measured at room temperature at KFK-2 at $\lambda = 590$ nm ($\ell = 0.5$ cm). The iron content is found on a pre-built grading graph.

2.6 Determination of iron in water

The natural sample — surface water (R. Kura) was preliminarily cleaned by filtration through a fine-porous glass Shota filter to remove slurry of sludge and soil, and boiled for 20 minutes. An aliquot of 10 ml was added to the extraction vessel, 0.4 ml of 0.1 M NaOH, 2.5 ml of 0.02 M H_2R and DFG in chloroform were added. The volume composition of phases did not exceed 1: 5 ($CHCl_3$: H_2O). The light absorption of the extracts was measured on KFK-2 at 540 nm in cuvettes with a layer thickness of 0.5 cm. The iron content was found according to a previously constructed calibration curve.

3. Results and Discussion
3.1 The Choice of the Extractant

Complexes of Fe (III) with H_2R are not extracted with organic solvents from solutions of weak acids. When introduced into an aqueous solution, Am forms MLC, which is extracted with organic solvents. $CHCl_3$, $C_2H_4Cl_2$, CCl_4, C_6H_6, $C_6H_5-CH_3$, C_6H_5Cl, iso-C_4H_9OH, iso-$C_5H_{11}OH$, n-C_4H_9OH and their mixtures were used to extract the complexes. The recoverability of the complexes was evaluated by the distribution coefficient (D) and the degree of extraction (R%) [9]. $CHCl_3$, $C_2H_4Cl_2$, CCl_4 and C_6H_5Cl were the best extractants. The rapid separation of the layers and the maximum value of the molar absorption coefficient were obtained by extraction of the complexes with chloroform. After a single extraction with $CHCl_3$, about 97.5-98.7% of iron was recovered as an ionic associate (Table 2). Further studies were conducted with chloroform. The concentration of iron in the aqueous phase was determined by the thiocyanate method [1], and the difference in the organic phase.

3.2 Effect of pH of the aqueous phase.

When iron (III) interacts with H_2R and Am, a colored complex is formed at a pH of 1.6-8.5 (Table 2). The study of the dependence of optical density on the pH of the solution showed that iron (III) with H_2R and Am at pH 3.5–6.0 is maximum with the formation of MLC. The complexes of Fe (III) with H_2R and Am are completely destroyed at pH <1.5. Obviously, this is due to a decrease in the concentration of the ionized form of H_2R. At pH 8.5, the complexes are practically not extracted, which seems to be associated with a decrease in the degree of protonation of Am and a change in the ionic state of iron (III).

3.3 Electronic spectra of the complexes

The chloroform extracts MLCs Fe(III)- R-Am have a maximum light absorption in the range 545-560 nm. The light absorption of the complexes Fe(III)-R-Phen and Fe(III)-R-Dip maximum at 590 and 595 nm, respectively. Knowing the absorbance and concentration chloroform extracts complexed iron (III), calculated from the molar absorption coefficients. Table 2 shows some characteristics of MLCs Fe(III)-R-Am.

3.4 Effect of ligand concentration, the amount of phase and time

The system Fe (III)-R-Am komplexes depends both on the sequence of draining the reactants and the concentration. For the formation and extraction of MLC, a 20-25- fold excess of complexing reagents is required; for example, the optimal conditions for formation and extraction of these compounds are provided by $(1.12-1.25)\times10^{-3}$ M R and $(0.90-1.30)\times10^{-3}$ M Am. Completeness of complexation and extraction is observed with an excess of the reagents. However it was found that the presence of excess of the reagent solution does not alter the absorbance of the color reaction. The calibration graph is linear in the range of Fe(III) concentration of 0.40-22.5 µg / ml.. Yield photometric detection Fe (III) in the form of MLC calculated by equation [17]. The limit of detection Fe(III) at $P = 0.95$ is 0.011 - 0.017 µg/ml. The absorbance does not decrease when the volume ratio of organic solvent and aqueous solution, equal to 1:20. MLC Fe(III) an H_2R and Am is formed immediately after mixing the component solutions. When pH is stable for days.

3.5 Determination of the molar ratios of the reacting components and the stability constant

The ratios of the components in the composition of the colored complexes formed are established by the relative yield and shift of equilibrium [17]. The ratio of components in Fe (III) MLC:R:Am=1:2:2. The structure of the complex was established by a spectrophotometric method in those pH ranges in which complexation occurs. It was found that under the conditions studied, the coordinating iron (III) ion in the formation of a complex with R - Phen (Dip) is Fe^{3+}, and in the formation of complexes with R-Am (the remaining Am) - $Fe(OH)^{2+}$. Phen and Dip (L) in an acidic environment once and twice protonated by heteroatoms [18] and form a RLC with a mixed sphere: $[FeR_2L](LH_2)$. The composition of the complexes formed with other amines corresponds: $[FeR_2(OH)](AmH)_2$.

To confirm the ratio of components in iron (III) RLC with HCTP and L, the complex compound was isolated in the solid state and analyzed for nitrogen, chlorine, iron, and sulfur. The following results were obtained:

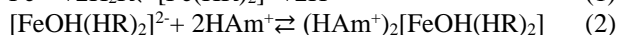|				
(PhenH$_2$)[Fe(HR)$_2$(Phen)]	Calculated,%:	Fe – 7.88;	Cl – 9.98;	S – 9.00;	N – 7.88.
	Found, %:	Fe – 7.95;	Cl – 10.07;	S – 9.13;	N – 7. 76.
(DipH$_2$)[Fe(HR)$_2$(Dip)]	Calculated,%:	Fe – 9.47;	Cl – 12.01;	S – 10.83;	N – 9.47.
	Found, %:	Fe – 9.45;	Cl – 12.40;	S – 10.02;	N – 9.55.

Thus, the results of the study lead to the conclusion that the ratio of Fe (III): R: Am = 1: 2: 2 in the extracted MLC.

By the method of intersection of curves [17], the stoichiometry and the conditional stability constant of homogeneous ligand complexes Fe(III)-R are determined. The results obtained by these methods are confirmed by the determination of stoichiometry and found that lgβ = 3.06 - 10.14. Taking into account the molar ratio of the components in the MLC, their conditional stability constants were determined. It was established that, in the presence of Am, the stability of the complexes increases by approximately two orders of

magnitude: lg β = 5.28 - 12.86 (Table 2).

3.6 Equilibrium and extraction constants

Based on the determination of the molar ratios of the reacting components, it can be assumed that the reactions of iron (III) with H₂R and Am proceed as follows:

$$Fe^{3+} + 2H_2R \rightleftarrows [Fe(HR)_2]^{2+} + 2H^+ \qquad (1)$$
$$[FeOH(HR)_2]^{2+} + 2HAm^+ \rightleftarrows (HAm^+)_2[FeOH(HR)_2] \qquad (2)$$

The equilibrium constant of reaction (2) is equal to:

Table 2: Conditions for the formation and properties of MLCs Fe (III) and H₂R with Am

Analitical chaaracterization	Reagents	Dip	Phen	DPG	o-Tol	м-Tol	p-Tol	o-Xyl	m-Xyl	p-Xyl
pH range of formation and extraction	HCTP	2.3-8.1	2.5-7.4	2.3-8.5	3.5-7.8	3.7-7.8	3.8-7.7	3.4-8.5	3.5-8.3	3.6-7.8
	HBTP	2.1-7.7	2.3-7.3	2.0-8.4	3.3-7.5	3.4-7.3	3.6-7.5	3.2-7.8	3.3-8.2	3.4-7.7
	HITP	1.9-7.5	2.1-7.0	1.8-8.5	3.1-7.4	3.2-7.1	3.3-7.4	3.0-7.6	3.1-8.1	3.2-7.6
(R, %	HCTP	97.5	98.7	97.7	98.6	98.3	98.7	98.0	98.5	98.5
	HBTP	97.6	97.5	97.8	98.5	98.3	98.7	98.1	98.4	98.7
	HITP	97.5	97.5	97.7	98.4	98.2	98.6	98.2	98.4	98.6
λ_{max}, nm	HCTP	595	594	550	557	560	545	552	555	558
	HBTP	594	593	547	555	556	541	548	550	553
	HITP	590	594	545	553	552	540	545	546	549
$\Delta\lambda$, nm	HBTP	312	311	267	274	277	262	269	270	273
	HBTP	304	308	259	266	265	254	261	262	265
	HITP	300	304	255	263	262	250	255	256	259
$\epsilon \times 10^4$	HCTP	4.2	4.0	4.5	4.3	4.2	4.1	3.9	3.7	3.5
	HBTP	4.0	3.9	4.4	3.9	3.7	3.5	3.6	3.5	3.4
	HITP	3.8	3.8	4.3	3.6	3.2	3.0	3.4	3.2	3.0
lgk$_{eq}$	HCTP	8.56	9.13	6.14	6.75	6.44	6.21	5.74	5.21	5.10
	HBTP	7.94	8.35	5.85	6.56	6.33	6.25	5.63	5.16	5.09
	HITP	7.35	7.91	5.52	6.55	6.43	6.32	5.51	5.42	5.35
lg k$_{ex}$	HCTP	10.2	9.56	9.11	4.15	3.65	3.13	5.56	5.12	4.64
	HBTP	9.73	9.31	8.87	3.87	3.20	2.65	5.23	4.80	4.30
	HITP	9.45	9.06	8.47	3.24	2.85	2.25	5.02	4.63	4.05
lgβ	HCTP	12.86	14.57	11.68	6.43	6.07	5.63	7.29	6.92	6.51
	HBTP	12.34	14.32	11.27	6.02	5.86	5.64	6.73	6.35	6.04
	HITP	11.83	14.02	10.95	5.78	5.56	5.28	6.31	5.97	5.51
Beer's law range, μg / ml	HCTP	0.4-20	0.4-22.	0.4-22.5	0.4-22.5	0.5-21.7	0.5-21.7	0.5-21.7	0.5-21.7	0.5-21.7
	HBTP	0.5-18	0.8-20.0	0.4-22.0	0.7-22.0	0.4-22.5	0.4-22.5	0.5-21.7	0.5-21.7	0.5-21.7
	HITP	06-18	1.0-21.0	0.5-21.0	0.4-21.8	0.5-22.0	0.4-22.0	0.5-21.7	0.5-21.7	0.5-21.7

Notes: R,% - recovery rates; lgk$_{eq}$ - equilibrium constant; lgk$_{ex}$ - constant extraction; lgβ conditional stability constants of complexes; ε - molar absorbance coefficients; Wholesale pH - optimum pH complexation; λ_{max} - maximum wavelength; Δλ - the difference between the maximum wavelength corresponding to the complex and reagent.

$$K_{eq} = \frac{\{(HAm)_2[FeOH(HR)_2]\}org}{[FeOH(HR)_2]_{aq}^{2-}\,[(HAm^+)^2]_{aq}}$$

Since the distribution coefficient (D)

$$D = \frac{\{(HAm)_2[FeOH(HR)_2]\}org}{[FeOH(HR)_2]_{aq}^{2-}}$$

hence

$$K_{eq} = \frac{D}{[(HAm^+)_2]}$$

From the last expression, we get

$$lg\,K_{eq} = lg\,D - 2lg\,[HAm^+]$$

Extraction constants were calculated by the equation

$$lgK_{ex} = lgD - 2lg\,[HR^{2-}] - 2lg[HAm^+]$$

The results of the calculation of the equilibrium constant of the reaction and extraction are shown in Table 2.

3.6 Effect of foreign ions

The effect of certain metal ions, as well as masking substances on the extraction-spectrophotometric determination of iron, has been studied under optimal conditions. The method for determination of Fe(III) with a reagent in the presence of α, α'-dipyridyl and 1,10-phenanthroline has the highest selectivity. For example, the determination of Fe(III) in the form of MLC Fe (III)-R-Phen does not interfere with more than 3,500 times the amount of alkali, alkaline earth metals, REE and Cl⁻, NO³⁻, SO₄²⁻; 1000-fold - In(II), Cd(II), Mg(II); 800-fold - Co(II), Ni(II), Mn(II) and U(VI); 400-fold - Cu(II), Pb(II), Cr(III) and Th (IV); 1000-fold - Al(III), Ga(III), In(III), Bi(III), Sb(III), Zr(IV), Hf(IV); 240-fold - Ti(IV), Nb(V), Ta(V); 200-fold V(V), Mo(VI) and W(VI).

The interfering effects of Cu (II), Cr (VI) and Mn (VII) were eliminated with thiourea; Ti (IV) - ascorebic acid, Zr (IV), Nb (V) and Ta (V) - fluoride ions.

If the analyzed solution contains V (V), Mo (VI) and W (VI), then two extractions are necessary. Extraction at pH <1.5 separates the indicated ions and by subsequent extraction at pH 3.5 - 6.0 the iron (III) compound with H2R is transferred

to the organic phase. Setting the pH 3.5 - 6.0 before the second extraction is carried out by adding a solution of ammonium acetate buffer.

3.7 Comparative characteristics of methods for determination of iron (III)

In table 3 shows the data for comparison of the analytical characteristics of methods for determining iron (III) with those already known [1, 7, 19] procedures. It can be seen that H_2R has advantages over other reagents: maximum light absorption is strongly mixed in the long wavelength region of the spectrum, the molar light absorption coefficient is much higher than the molar light absorption coefficients of other complexes.

Table 3: Data to compare analytical methods for determining the characteristics of Fe(III) with known reagents

Reagents	pH_{op}(solvents)	λ, nm	$\Delta\lambda$, nm	$\varepsilon \times 10^{-4}$	[Ref.]
Gallic acid -An	6.8 – 7.8	650	380	0.56	[19]
Ferron	4.9-5.3 4.9-5.3 2.9-3.2	365, 600, 520	-	0.794 0.571	[1]
Catechol – An	5.1-5.6 ($CHCl_3$ + C_6H_6)	540	262	0.2	[19]
Thiosalicylic acid-Phe	5-6 ($CHCl_3$)	570	288	1.2	[19]
Salicylic acid	~ 1.2 (H_2O)	528	-	0.378	[1]
2,3-dimethylpyrazolone - Phen	2.8-3.2 (H_2O)	470	97	1.05	[7]
2,3-dimethylpyrazolone -Phen	3.6-4.1 (H_2O)	451	78	0.72	[7]
HCTP - Phen	3.0-6.0 ($CHCl_3$)	594	311	4.0	Proposed method
HCTP - Dip	3.5-6.0 ($CHCl_3$)	595	312	4.2	
HBTP - Phen	2.8-5.7 ($CHCl_3$)	593	308	3.9	
HBTP - Dip	3.3-5.7 ($CHCl_3$)	594	304	4.0	

4. Analytical applications

The proposed method is used to determine the trace amounts of iron in natural waters (Kura River), in fruits and berries (in white, red cherry and strawberry) (Table 4).

Table 4: Results of the determination of iron in natural waters (r. Kura) and in fruit (in white, red cherries and strawberries) (n = 5, P = 0.95).

Analysis object	Added, μg	Found, μg	$\overline{X} \pm \dfrac{t_P S}{\sqrt{n}}$
White Cherry	3.49	13.50	13.50±0.03
Red Cherry	4.21	14.40	14.40±0.05
Strawberry	5.11	10.16	5.16±0.04
Water	7.7	9.20	9.19±0.02

5. Conclusions

1. The purpose of this work is the development of highly selective methods of photometric determination of iron (III) in the environment, in particular in natural waters (Kura river) and fruits (white and red cherries and strawberries) using hydroxy halogen thiophenol (H_2R) - 2- hydroxy-5-chlorothiophenol (HCTP), 2-hydroxy-5-bromothiophenol (HBTP) and 2-hydroxy-5-iodothiophenol (HITP) and the hydrophobic amine (Am) -1,10-phenanthroline (Phen) α, α'- dipyridyl (Dip), diphenylguanidine (DPG), *o, m, p*-toluidine (o-Tol) (*m*-Tol) (*p*-Tol), *o. m, p*-xylidine (*o*-Xyl) (*m*-Xyl), (*p*-Xyl).

2. The dependence of the ionization constants (pK_a) H_2R the solution ionic strength $pK_n = f(\mu)$ in the range of $\mu = 0 - 1$ linear and described by the equations:

HCTP: $pK_1 = 5.2762 – 0.5506\sqrt{\mu}$; $pK_2 = 10.7289 – 0.4028\sqrt{\mu}$.
HBTP: $pK_1 = 5.2643 – 0.6697\sqrt{\mu}$; $pK_2 = 10.5341 – 0.4191\sqrt{\mu}$.
HITP: $pK_1 = 5.1483 – 0.4634\sqrt{\mu}$; $pK_2 = 10.3621 – 0.5066\sqrt{\mu}$.

3. $CHCl_3$, $C_2H_4Cl_2$, CCl_4 and C_6H_5Cl were the best extractants. The rapid separation of the layers and the maximum value of the molar absorption coefficient were obtained by extraction of the complexes with chloroform.

After a single extraction with $CHCl_3$, about 97.5-98.7% of iron was recovered as an ionic associate.

4. When iron (III) interacts with H_2R and Am, a colored complex is formed at a pH of 1.6-8.5. The study of the dependence of optical density on the pH of the solution showed that iron (III) with H_2R and Am at pH 3.5–6.0 is maximum with the formation of MFA. Electronic spectra of the complexes extracts of chloroform MLC Fe (III) - R-Am have a maximum light absorption in the range of 545-560 nm. The light absorption of the Fe (III) -R-Phen and Fe (III) -R-Dip complexes is maximum at 590 and 595 nm, respectively.

5. The ratios of the components in the composition of the colored complexes formed are established by the relative yield and shift of equilibrium. The ratio of components in Fe (III) MLC: R: Am=1:2:2.

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