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Extraction-photometric determination of bismuth in the ointment «Liniment balsamic» in the quaternary water – dithiopyrylmethane – trichloroacetic acid – orthophosphoric acid system

The article is devoted to the investigation of the mutual influence of bismuth, dithiopyrylmethane, trichloroacetic and orthophosphoric acids in a four-stratified system with a single liquid component, water.The results of the developed alternative method for determining the microgram amounts of bismuth in pharmaceutical preparations using this system, which does not contain toxic organic solvents, are presented. The coloring complex of bismuth with dithioerythritol yellow allowed using photometry at 354 nm and 447 nm as a method of monitoring the concentration of bismuth. The appearance of two maxima on the absorption spectrum indirectly indicates the formation of Bi-DTM complexes in different tautomeric forms, namely, thion and thiol. Comparing the obtained data, it is found that the complexation of phosphate in the media is similar to sulfuric acid, and the formation of the red complex of bismuth with dithioerythritol prevents high value of acidity. The influence of extraneous ions on the determination of bismuth (III) was investigated. Selection of the ions was due to their presence in various alloys, pharmaceutical preparations, etc. objects, and containing trace amounts of bismuth. The results of the developed alternative methods are consistent with the stated content of bismuth in ointment A.V. Vishnevsky «Liniment balsamic».

Keywords: dithiopyrylmethane, bismuth, exfoliating extraction system, extraction-photometric determination, complexation, the method of «saturation», heavy metal, medicine, medicament.

Introduction

Bismuth is a heavy metal, the compounds of which have a resorptive and local effect, which has allowed the development of a sufficient number of pharmaceutical preparations of different effects. These drugs are widely used and used in medicine. Bismuth in the human body is easily bound to proteins, so drugs based on it have antiseptic and astringent properties [1]. Bismuth has a moderate toxicity, but the mechanism of toxic effects of bismuth salts has been poorly studied.

It is known [2] that dithiopyrylmethane interacts with Au (III), Bi (III), Mo (VI) in a wide range of sulfuric and hydrochloric acids, forming stable colored compounds suitable for photometric determination. Unlike yellow complexes of gold and molybdenum, bismuth forms a complex compound of red-cherry color, stable for a long time. The ratio Bi:DTM = 1:2 was found by the method of equilibrium shift.

The extraction-photometric determination of bismuth with dithiopyrylmethane in the presence of thiocyanate, iodide, and perchlorate ions is described in [3, 4]. The absorption maxima of bismuth complexes in the organic phase, with the ratio Bi:DTM = 1:3, are at 490, 520, and 540 nm. The method is used for analysis of ores and their enrichment products.

Bismuth with dithiopyrylmethane in the presence of perchlorate ions forms a ternary complex, which is extracted from aqueous solutions with dichloroethane or a mixture with dimethylformamide [5].The ratio of the components in the extracted compound is as follows Bi:DTM:ClO_4^- = 1:3:3.

The aim of the study was to modify the above-described extraction-photometric determination of bismuth [4] by replacing the traditional extraction system with an organic solvent with a single-component liquid-water system. This system relates to non-traditional extraction systems, since extraction proceeds due to delamination of the aqueous-organic medium when the salting out agent is introduced. Stratification occurs due to the chemical acid-base interaction of trichloroacetic acid (TCAA) with dithiopyrylmethane (DTM) and salting out when orthophosphoric acid is added.

Experimental

Reagents. We used an aqueous solution of bismuth (C_{Bi} = 4.1×10^{-3} mol/L) and phosphate solution of dithiopyrylmethane (DTM) (C_{DTM} = 0.02 mol/L).The optimal ratio of the acids entering the system was chosen by isomolar series for the extraction-photometric determination of bismuth with dithiopyrylmethane, namely, $V_{H_3PO_4}$ (C = 10.3 mol/L):V_{CCl_3COOH} (C = 6.4 mol/L) = 1:1. The total volume of acids was 5 mL. As the real object of the selected ointment at the A.V. Vishnevsky «Liniment balsamic» with the content of bismuth in it is 1.74 %.

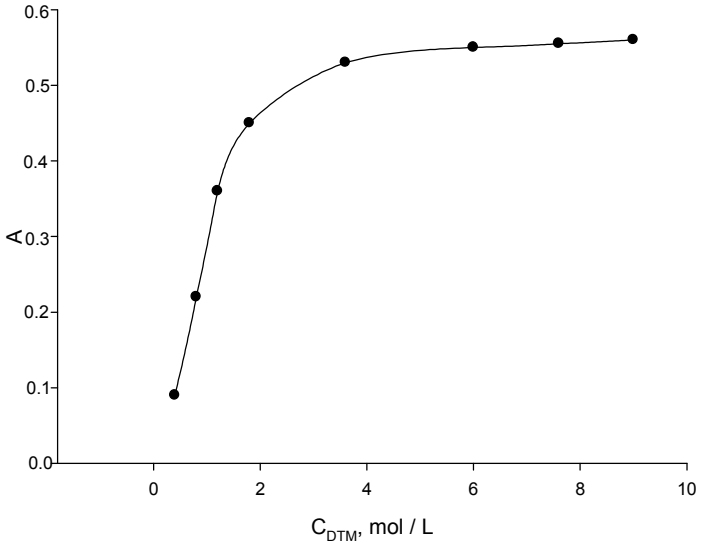
Equipment. The absorption spectrum of the complex in the extract was taken with respect to the reference solution on a spectrophotometer «Spekol-10». To remove the spectra all solutions were prepared in 10 mL volumetric tubes.

Results and discussion

In the system under study, bismuth forms a yellow complex with dithiopyrylmethane. Two maxima at 354 nm and 447 nm are observed on the absorption spectrum, which apparently indicates the occurrence of dithiopyrylmethane in the complex in various tautomeric forms of thionic and thiol.

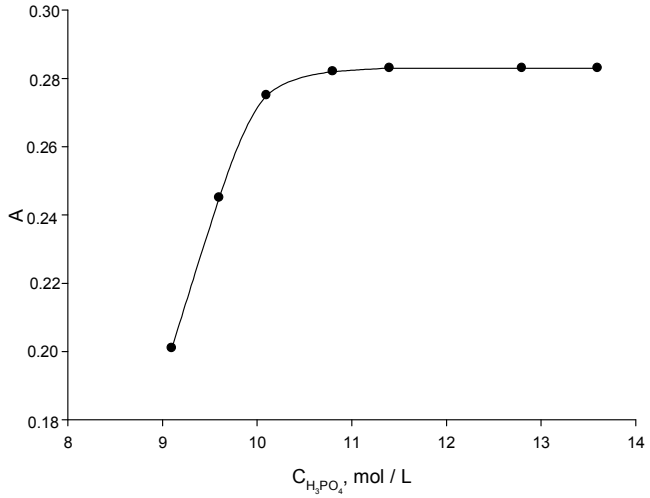
Absorption spectra of extracts of bismuth complexes with DTM in orthophosphoric and sulfuric acid systems have been studied, as well as the dependence of the absorption spectra of the complex extract in the orthophosphoric acid system. Comparing the data obtained, it was established that complexation in phosphoric acids occurred similarly to sulfuric acid. The formation of a red complex of bismuth with dithiopyrylmethane is prevented by a high value of the acidity of the medium. In our case, with a decrease in the acidity of the medium, stratification disappears, and therefore a yellow complex is observed in the system. Two independent methods of «saturation» and Bent-French determined the Bi:DTM ratio in the compound, it was 1:2, which agreed with the literature data [3].

The choice of optimal conditions was carried out at two wavelengths. Dependences of the optical density on the concentration of the reagent (Fig. 1), the acidity of the medium (Fig. 2), and the color development time were studied. It was established that the bismuth complex with dithiopyrylmethane was stable during the day.



C_{Bi} = 4.1×10^{-3} mol/L; λ = 354 nm

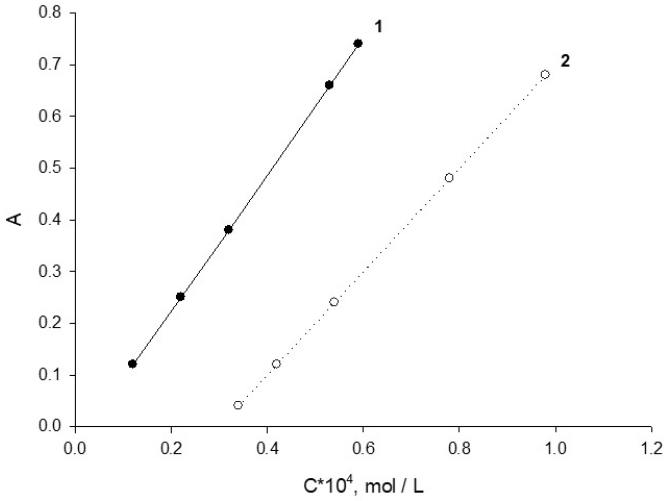
Figure 1. Dependence of the absorbance of the extract of bismuth (III) complex with DTM on the concentration of the reagent



$C_{Bi} = 4.1\times10^{-3}$ mol/L; λ = 447 nm

Figure 2. Dependence of the absorbance of the extract of bismuth (III) complex with DTM on the concentration of orthophosphoric acid

The dependence of the absorbance on the bismuth concentration was studied under the selected optimal conditions, namely, 2.0 mL of 10.3 M H_3PO_4, 2.5 mL of 6.4 M CCl_3COOH, 0.5 mL of 0.02 M phosphoric solution of DTM, and calibration curves were plotted for two wavelengths (Fig. 3).



1 — λ = 354 nm; *2* — λ = 447 nm

Figure 3. Dependence of the optical density of the extract containing bismuth (III) complex with DTM on the concentration of bismuth reagent

When assessing the reproducibility of the method for determining bismuth with dithiopyrylmethane, it was established that the relative standard deviation did not exceed 0.04 (Table 1). The apparent molar absorptivity was also calculated to be $\varepsilon_{app} = 1.2\times10^4$ (λ = 354 nm) and $\varepsilon_{app} = 1.1\times10^4$ (λ = 447 nm).

Table 1

The determination of bismuth in solutions of its salts (λ = 354 nm, n = 3)

Introduced, m, μg	Found ($m_i \pm \delta$), μg	S_r
8.0	8.2 ± 0.9	0.04
16.9	16.9 ± 0.7	0.03
27.9	27.3 ± 0.6	0.01

The influence of extraneous ions on the determination of bismuth (III) was studied. The choice of ions was due to their presence in various alloys containing micro-quantities of bismuth: steel, CAM, etc. The criterion of influence was taken by the deviation of the absorbance by 3–5 % from its value, measured in the determination of bismuth without extraneous ions. Interfere with Cu (II), Cr (VII), Mo (VI), Ti (IV) do not interfere with Al (III), Cd (II), Fe (III), Mn (II), Ni (II), Pb (II), Si (IV), VO_4^-, Zn (II) in certain quantities (Table 2). Thus, the procedure for determining bismuth is selective in the presence of Fe (III), but it is necessary to resort to masking Cr (VII), Cu (II), Mo (VI), Pb (II), and Ti (IV).

Table 2

The influence of extraneous ions on the determination of bismuth

The name of the ion	$m_{Bi} : m_{ion}$
Si (VI)	1:100
Mn (II)	1:270
Ni (II)	1:114
VO^{4-}	1:5
Zn (II)	1:80
Pb (II)	1:1
Cd (II)	1:2
Al (III)	1:8
Fe (III)	1:500
Cu (II), Cr (VII), Mo (VI), Ti (IV)	Disturb the definition

Since bismuth is contained not only in alloys, but also in pharmaceutical preparations, the ointment according to A.V. Vishnevsky «Liniment balsamic» with the content of bismuth in it is 1.74 %.2.0 mL of H_3PO_4 (10.3 M), 2.5 mL of CCl_3COOH (6.4 M), 0.5 mL of a phosphate solution of dithiopyrylmethane (0.02 M) and alternating the amount of bismuth, namely, 5.0 μg, 10.0 μg, 13.0 μg, 16.9 μg, 19.9 μg, and 30.6 μg were used to construct the calibration curve.

After sedimentation and phase separation, the absorbance of the extract was measured at $\lambda = 354$ nm on a spectrophotometer «Spekol-10». Based on the obtained data, a calibration graph was plotted in coordinates A-mBi (μg) and processed by OLS. The regression equation had the form: A = 0.032 m. Then a sample of ointment 0.09640 g was dissolved in 6.4 M CCl_3COOH in a 25 mL volumetric flask. 2.0 mL of H_3PO_4 (10.3 M), 0.5 mL of a phosphate-acid solution of DTM (0.02 M); 2.1–2.3 mL of CCl_3COOH (6.4 M) and aliquots of the dissolved ointment 0.4–0.2 mL were added to the measuring tubes. After settling and separating the phases, the absorbance was measured and the mass fraction of bismuth in the pharmaceutical preparation was calculated. The results of the determination are given in Table 3. The value of the relative standard deviation does not exceed 0.04.

Table 3

Determination of bismuth in the ointment «Liniment Balsamic»

Content ω_{Bi}, %	Sr	$\omega \pm \delta$, %
1.74	0.01	1.74 ± 0.02

Conclusions

Thus, the mutual influence of bismuth, dithiopyrylmethane, trichloroacetic and orthophosphoric acids in a four-stratified system with a single liquid component, water, was studied. The influence of extraneous ions on the determination of bismuth (III) was studied. The results of the developed alternative method for determining the microgram amounts of bismuth in pharmaceutical preparations using this system, which does not contain toxic organic solvents, are consistent with the claimed bismuth content in the ointment according to A.V. Vishnevsky «Liniment Balsamic».

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«Бальзамдық линимент» жақпамайында висмутты су – дитиопирилметан – трихлорсірке қышқылы – ортофосфор қышқылы жүйесінде экстракциялы фотометрлік әдіспен анықтау

Мақалада висмуттың су – дитиопирилметан – трихлорсірке қышқылы – ортофорсфор қышқылы жүйесіндегі әсері зерттелген. Фармацевтикалық препараттардан жоғарыда айтылған жүйеде (құрамында улы органикалық ерітінділері жоқ) микрограмм мөлшердегі висмутты анықтаудың қосымша әдісінің нәтижелері келтірілген. Висмут кешенінің дитиопирилметанмен сары түске боялуы висмут концентрациясын 354 нм және 447 нм-дегі фотометрия әдісімен анықтауға мүмкіндік берді. Жұтылу спектрінде екі максимумның түзілуі Bi-ДТМ комплексінің әртүрлі таутомерлік — тионды және тиолды түрде түзілгенін көрсетеді. Алынған нәтижелерді салыстыра отырып, комплекс түзілу фосфорлы-қышқылдық ортада күкіртті-қышқылдық ортаға ұқсас жүретіні анықталды, ал висмуттың дитиопирилметанмен қызыл түсті комплекс түзуіне орта қышқылдығының жоғары болуы кедергі келтіретіні белгілі болды. Жұмыста висмут (III) ионын анықтауда басқа иондардың әсері зерттелді. Иондарды таңдау кезінде құрамында микромөлшерде висмут кездесетін әртүрлі балқымалар, фармацевтикалық препараттар және басқа да заттар негізге алынды. Өңделген әдістің нәтижелері А.В. Вишневский бойынша «Бальзамдық линимент» жақпамайының құрамындағы висмут мөлшерімен үйлесті.

Кілт сөздер: дитиопирилметан, висмут, қабатты экстракцияланған жүйе, экстракциялы фотометрлік анықтау, комплекс түзілу, «қанығу» әдісі, ауыр металл, медицина, дәрілік препараттар.

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Экстракционно-фотометрическое определение висмута в мази «Линимент бальзамический» с помощью четверной системы вода – дитиопирилметан – трихлоруксусная кислота – ортофосфорная кислота

Статья посвящена исследованию взаимного влияния ионов висмута, дитиопирилметана, трихлоруксусной и ортофосфорной кислот в четверной расслаивающейся системе с единственным жидким компонентом — водой. Приведены результаты разработанной альтернативной методики определения микрограммовых количеств висмута в фармацевтических препаратах с помощью указанной системы, не содержащей токсичных органических растворителей. Окрашивание комплекса висмута с дитиопирилметаном в желтый цвет позволило применить в качестве метода контроля концентрации висмута фотометрию при 354 нм и 447 нм. Появление в спектре поглощения двух максимумов косвенно указывает на образование комплексов Bi-ДТМ в разных таутомерных формах: тионной и тиольной. Сопоставляя полученные данные, установили, что комплексообразование в фосфорнокислых средах происходит аналогично сернокислым, а образованию красного комплекса висмута с дитиопирилметаном мешает высокое значение кислотности среды. В статье исследовано влияние посторонних ионов на определение висмута (III). Выбор ионов обусловливался их наличием в различных сплавах, фармацевтических препаратах и других объектах, содержащих микроколичества висмута. Результаты разработанной альтернативной методики согласуются с заявленным содержанием висмута в мази по А.В. Вишневскому «Линимент бальзамический».

Ключевые слова: дитиопирилметан, висмут, расслаивающаяся экстракционная система, экстракционно-фотометрическое определение, комплексообразование, метод «насыщения», тяжелый металл, медицина, лекарственные препараты.

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