Radioactive Kryptonates in Volumetric Analysis (I)
Radioactive Kryptonates — New Chelatometric Indicators

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*Dedicated to Prof. Ing. S. Stankoviansky on the occasion of his 60 birthday
and to Prof. Dr. M. Dillinger on the occasion of his 65 birthday*

A method was worked out for using radioactive kryptonates as end-point indicators in chelatometric titrations. The end-point is determined with the help of solid radioactive kryptonate AB[^{85}Kr], added into the tested solution before the beginning of titration. After exceeding the end-point, the excess of the added chelate-forming agent reacts with radioactive kryptonate liberating radioactive krypton ^{85}Kr.

Principles of the titration method, methods for preparing radioactive kryptonated indicators, experimental results of kryptonation and a study of the properties of prepared radioactive kryptonates from the point of view of their application as indicators in radiochelatometric titrations are given in this paper.

The importance of volumetric analysis using radiometric end-point indication (so-called radiometric titration), has recently greatly increased, owing to the working out of new methods for separating titration components and principally owing to new titration processes [1, 2].

New possibilities of further development in radiometric titration processes are represented by radioactive kryptonates, which were first suggested for use in the end-point indication by D. J. Chleck [3].

The denomination ,,radioactive kryptonates" is used to indicate solid materials into which radioactive nuclide ^{85}Kr was introduced. The very first experiments and practical applications have shown the use of this group of materials in the most varied fields of science and technology. A systematic study of the preparations, properties and application of radioactive kryptonates was given in 1957 by a group of research workers led by D. J. Chleck in the research laboratory of the Tracerlab firm [4, 5]. Radioactive kryptonates have so far been used to detect and determine non-radioactive compounds, for instance, components and trace impurities in the air (oxygen, ozone, sulfur dioxide, etc.), to determine gaseous hydrogen, traces of water in organic liquids, to follow the reaction rate and mechanism of chemical reactions, etc.

For the preparation of radioactive kryptonates is used ^{85}Kr for its advantageous nuclear properties (long half-life, suitable energy of β radiation). Krypton is an inert gas (aerogen) and under normal conditions does not enter metabolic systems and therefore from the biologic aspect is very safe.

The basic question of preparing radioactive kryptonates is the incorporation of atoms of radioactive krypton (^{85}Kr) into solid carrier material. The technique of

kryptonation is directed by the nature of the carrier and the requirements of radioactive kryptonate. Atoms of radioactive krypton are built into the solid carrier especially in the substituting or interstitial position. In the first case they fill in vacancies in the crystal lattices and in the second case they are caught between the structure elements of the carrier lattice.

For the preparation of radioactive kryptonates the following technique is used:
— bombarding of target material with ions ^{85}Kr accelerated in the electric field;
— diffusion of radioactive krypton into the solid target material;
— crystallization of kryptonated material from melt in the atmosphere of radioactive krypton;
— sublimation of kryptonated material in the atmosphere of radioactive krypton.

Applications of radioactive kryptonates are founded on the finding that the chemical or physical process, which ruptures the surface or crystal lattice of radioactive kryptonate, causes the liberation of a proportionate quantity of gaseous radioactive krypton. In kryptonates, krypton is bound by non-valent forces regardless of the structure of the carrier and the distribution of krypton in it.

Some methods of preparing radioactive kryptonates, the characteristics of their properties and practical applications in different spheres of science and technology have been described in detail in our papers [6, 7].

In the application of radioactive kryptonates for the end-point indication an auxiliary reaction of radioactive kryptonate with an excess amount of titrant solution (after exceeding the end-point), which will liberate the radioactive krypton, is employed. The reaction product being a gas (^{85}Kr), it is relatively easy to separate it from the other titration components, which are in the solid (indicator) and liquid (tested and titrant solution) phase.

Radioactive kryptonates can be used as end-point indicators when the kryptonated solid material does not react with the tested solution but reacts with the titrant solution.

So far only three papers have dealt with kryptonates as end-point indicators, which rather have the character of preliminary notes. because the usual analytical data are missing. These are: titration of fluoride ions with titrant solution of thorium nitrate using kryptonated zinc foil [3], titration of sodium hydroxide with titrant solution HCl using radioactive kryptonate of magnesium or zinc [8] and titration of thorium with titrant solution of sodium fluoride using radioactive kryptonate of glass as end-point indicator [9].

In these papers are given introductory studies to the possibilities of using some radioactive kryptonates as end-point indicators in radiochelatometric titrations.

Principle of method

In one method of end-point indication by radiochelatometric titration, solid radioactive indicators are used, which after exceeding the end-point are dissolved and the indication is carried out on the basis solution radioactivity increase. In these titrations was used as indicator ^{110m}Ag labelled precipitate $AgIO_3$ [10]. A disadvantage of these titrations is that it is uncomfortable and risky work with radioactive precipitate and solution, great laboriousness of titration and difficulties with the automation of the titration process. The process suggested by us removes the disadvantages of these titrations. It is marked by a combination of the process according to [10] and the use of radioactive kryptonates.

The titration of cation M with chelate-forming reagent (titrant solution) C is considered according to the reaction:

$$M + C \rightleftharpoons MC. \tag{A}$$

The end-point is determined with the help of solid radioactive kryptonate AB [^{85}Kr], added to the tested solution before the beginning of titration. After the termination of reaction (A) the chelate-forming titrant solution reacts with this indicator giving rise to a soluble compound according to the reaction:

$$AB[^{85}Kr] + C \rightleftharpoons AC + B + {}^{85}Kr \tag{B}$$
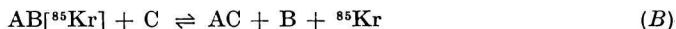
where gaseous radioactive krypton is liberated. The equilibrium of the reaction (B) is characterised by the stability constant K_{MC} of the complex MC and the product of solubility $L_{AB[^{85}Kr]}$ of solid radioactive kryptonate AB[^{85}Kr].

The titration can be carried out under the conditions that:

a) $pK_{MC} > pK_{AC}$;

b) the ratio between the stability constant of the complex AC and the solubility product of the kryptonate AB[^{85}Kr] allows the dissolution of kryptonate by the chelate-forming reagent according to reaction (B).

In the course of titration up to end-point, reaction (A) takes place. The radioactivity of the kryptonate is constant. After exceeding the end-point, the excess of the additional chelate-forming reagent C reacts with cations A together with a gradual dissolution of radioactive kryptonate and liberation of radioactive krypton ^{85}Kr.

The titration may be as follows:

a) discontinuous — by measuring the radioactivity of the solid indicator after every addition of titrant solution. By graphically illustrating the dependence of the measured radioactivity on the volume of the titrant solution addition a titration curve is obtained, from which the end-point is subtracted;

b) continuous — where the titrant solution is introduced continuously and the liberated ^{85}Kr is carried away, for instance, by nitrogen as a carrier gas into a passage detector of radioactivity connected with an ratemeter. The titrating curve is automatically registered by recording equipment.

On this principle it is possible to realize radiochelatometric titrations by a suitable chelate-forming reagent (conditions a and b being fulfilled), which quantitatively react with ions of the determining element using a suitable radioactive kryptonate.

In this work, use was made of chelatone III as titrant solution and as indicator, radioactive kryptonate $AgIO_3$, $Y_2(C_2O_4)_3$ and others. Thus cations Ca^{2+}, Sr^{2+}, Mg^{2+} and others were titrated by chelatone III using kryptonate $AgIO_3[^{85}Kr]$ at pH $\sim$ 10 and Fe^{3+} using $Y_2(C_2O_4)_3[^{85}Kr]$ in the presence of tartaric acid at pH $\sim$ 5. The individual concrete determinations will be dealt with in our later papers.

Experimental

Preparation of non-active carriers

Use was made of silver iodate and yttrium oxalate as carriers of radioactive krypton ^{85}Kr, which were then used as indicators in the form of radioactive kryptonates in radiochelatometric titrations.

Silver iodate was prepared by precipitating a saturated solution of potassium iodate

by a saturated solution of silver nitrate. The precipitate after drying and smearing was kept in dark bottles.

Yttrium oxalate was prepared by an addition of oxalic acid into a neutral solution of yttrium nitrate. It forms nonahydrate $Y_2(C_2O_4)_3 \cdot 9H_2O$.

^{85}Kr *used in the experiment and its dosage*

The commercially supplied radioactive preparation ^{85}Kr (Radiochemical Centre, Amersham, Great Britain) with total activity 1 Ci was divided into 8 parts by the procedure already described [9].

The withdrawal and dosing of radioactive krypton was made by the procedure and equipment already described [11], which allows the withdrawal of krypton under atmospheric pressure and control of its relative amount. In this equipment radioactive krypton ^{85}Kr is adsorbed on activated carbon at liquid nitrogen temperature. By desorption of ^{85}Kr from carbon and with the help of a mercury manostat the dosing equipment is filled with radioactive krypton under atmospheric pressure. The withdrawal of krypton is done through a rubber membrane under the mercury surface by suction into a syringe. Before a repeated withdrawal of ^{85}Kr, pressure in the dosing equipment is again set to atmospheric pressure with the help of the mercury manostat.

Preparation of radioactive kryptonated indicators by ion bombardment

For the preparation of radioactive kryptonates of low specific activities, a suitable method is that used by Č. Jech [12, 13]. Ions ^{85}Kr are accelerated in a pulsed high-frequency electric field produced by a Tesla transformer. This method was used in our experiments. A diagram of the equipment used is in Fig. 1, photograph in Fig. 2. The adsorbing properties of activated carbon are utilised both for the preparation of vacuum in the bombarding apparatus and the binding of radioactive gas. By a change of temperature of activated carbon are realized both the adsorption and desorption of gas [9].

The sample is placed in the space for samples. The apparatus is connected by ground joint *10*, the vacuum valve is opened *9* and the ampoule with activated carbon *4* is
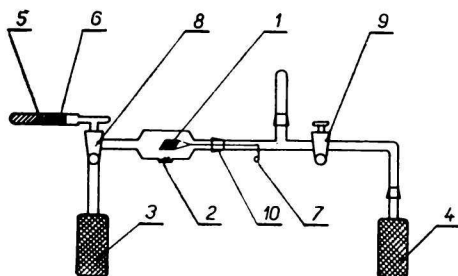

Fig. 1. Equipment for the preparation of radioactive kryptonated indicators by ion bombardment according to Č. Jech. *1.* anode; *2.* cathode; *3., 4.* activated carbon; *5.* tube with metallic calcium; *6.* glass wool; *7.* platinum eye; *8., 9.* vacuum valves; *10.* ground joint.
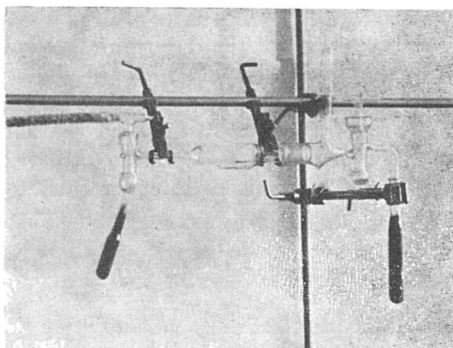
Fig. 2. Photograph of equipment for the preparation of radioactive kryptonates by ion bombardment.

submerged into liquid nitrogen. Air is adsorbed by activated carbon and vacuum is controlled by a Tesla vacuum tester. After reaching satisfactory vacuum, valve 9 is closed and valve 8 is opened. ⁸⁵Kr fills the anode space. Anode 1 is formed by an aluminium sheet fixed on a platinum wire which is sealed in a glass vacuum apparatus in such a way that a little eye 7 is jutting out on the outer side. Ions ⁸⁵Kr are accelerated by a pulsed high-frequency electric field of a Tesla vacuum tester. One pole of the tester is joined to the eye forming the anode and the other pole of the tester (where for increasing the area there is an aluminium sheet) forms the cathode 2. The cathode is placed exactly under the sample. The discharge takes place in short intervals (a few seconds) to prevent both glass and sample placed under it from getting too hot. Then ampoule 3 is submerged into liquid nitrogen and ⁸⁵Kr is adsorbed on activated carbon. Valve 8 is closed and valve 9 is opened to increase pressure in apparatus and sample can be removed.

Ampoule 3 filled with activated carbon with adsorbed krypton is connected with a tube filled with metallic calcium 5. This one is to collect the remains of air from gaseous krypton. The ground joint 10 is for the purpose of filling the apparatus with krypton.

Preparation of radioactive kryptonated indicators by the diffusion technique

The theoretical problems of kryptonation by the diffusion technique have been dealt with in our paper [9]. Kryptonation technique at low pressure is described in paper [14], at high pressures in paper [15].

Kryptonation was carried out in thick wall glass capillaries 24 cm long. The capillary is first cleaned with cotton wound on a piece of wire which reaches the bottom. Then a small amount of material for kryptonation is put in, pushed to the bottom by means of a wire, not to spill it about in filling with krypton-85. The walls are cleaned from the grains of the material with cotton.

The mouth of the capillary which sample 2 is submerged into the vessel with mercury 1 and with syringe 3 air is sucked out and the whole capillary is filled with mercury (Fig. 3). The needle is withdrawn and the needle of the syringe filled with ⁸⁵Kr is introduced into
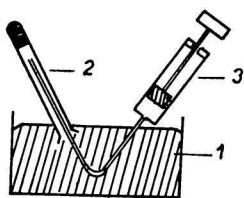

Fig. 3. Filling of capillars with radioactive krypton.
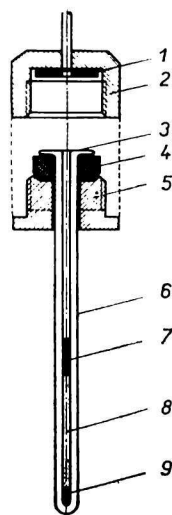1. vessel with mercury; 2. sample in capillary; 3. syringe.

Fig. 4. Diffusion kryptonation.
1. matrix sealing; 2. matrix; 3. ground part of capillary; 4. rubber sealing; 5. screw with opening; 6. glass capillary; 7. movable mercury plug; 8. gaseous ⁸⁵Kr; 9. sample.

the capillary. By pressing in krypton, mercury is pressed out of the capillary leaving a 4—8 mm closure at the mouth of the capillary.

A rubber sealing is drawn over the capillary and is tied to the handle (Fig. 4). The capillary is connected with a nitrogen bomb by means of a copper spiral tube through a working manometer. After thorough sealing and closed needle valve, the valve on the nitrogen bomb is opened. The working pressure on the manometer is set, being careful that mercury does not get into the kryptonated material, but must be separated from it by krypton-85. Working pressure is set by means of the needle valve.

After the required kryptonation period the bomb valve is closed and the sealing matrix between the bomb and needle valve is loosened. Then the needle valve is opened whereby pressure in the apparatus is equilized with atmospheric pressure. The capillary is taken out, the mercury removed, the end of the capillary is cut and broken off. The radioactive kryptonate is placed into a ground neck vessel.

Experimental results of kryptonation

Elementary iodine was liberated from silver iodate in bombarding with ions ^{85}Kr in vacuum. Therefore, it was not possible by this method to prepare radioactive kryptonate $AgIO_3$.

The technique of ion bombarding proved very successful in the preparation of radioactive kryptonate of yttrium oxalate. The radioactive kryptonate thus obtained had

Table 1

Kryptonation results of $Y_2(C_2O_4)_3 . 9H_2O$ by ion bombardment

Test No.	Amount of $Y_2(C_2O_4)_3 . 9H_2O$ [mg]	Duration of kryptonation [sec]	Specific activity [cpm/g]
1	1.7	10 × 10	7 740 000
2	9.4	7 × 10	2 700 000
3	6.5	3 × 10	1 270 000
4	8.5	3 × 5	460 000

Table 2

Kryptonation results of $AgIO_3$ by the diffusion technique

Test No.	Amount of $AgIO_3$ [mg]	Pressure [atm]	Duration of kryptonation [hours]	Specific activity [cpm/g]
1	19.2	8.5	2.5	11 600
2	21.0	8.5	42	42 000
3	28.4	50	2.5	35 000
4	31.3	50	62	1 690 000
5	23.1	27	26	23 900

a high and increasing specific activity with the increasing period of kryptonation. The results and parameters of kryptonation $Y_2(C_2O_4)_3 \cdot 9H_2O$ are given in Tab. 1.

Silver iodate was kryptonated by the diffusion technique at laboratory temperature. Kryptonation was first carried out at low pressures for various time duration. The specific activity of radioactive kryptonates was, however, very low and, therefore, kryptonation under higher pressure and longer time duration was resorted to. Thus were obtained specific activities necessary for further indicator application of radioactive kryptonate $AgIO_3$. The results and parameters of kryptonation are in Tab. 2.

On the basis of these results for further use, radioactive kryptonate $AgIO_3$ was prepared under optimum conditions (pressure ~ 50 atm, temperature ~ 20 °C, duration of kryptonation ~ 60 hrs.).

Properties of prepared radioactive kryptonates and discussion

From the properties of prepared radioactive kryptonates and from the point of view of their application as indicators in chelatometric titrations, it is important for us to know especially dekryptonation (liberation ^{85}Kr) of a given radioactive kryptonate under different conditions. We studied, therefore, the activity decrease of radioactive kryptonate in air under laboratory conditions, under the influence of the titrating milieu and under the influence of the titrant solution, for which they are to be used as indicators. The radioactivity of kryptonates, which were prepared, was measured in a manner and by equipment which will be described for concrete applications in further issues of this series. Absolute specific activities of radioactive kryptonates have not been determined, because in titrations, only
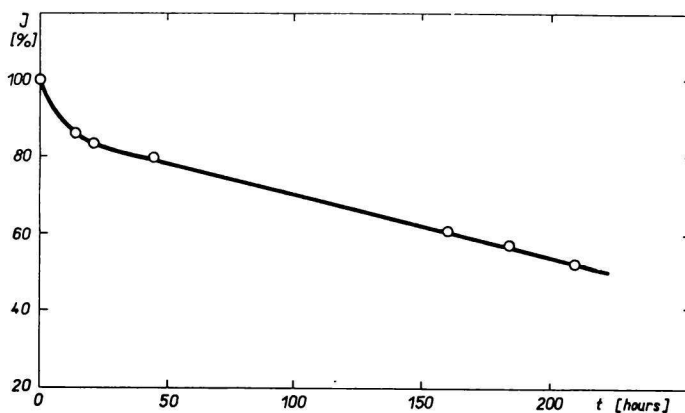
Fig. 5. Dependence of activity decrease of radioactive kryptonate of $AgIO_3$ in air at laboratory conditions on time.
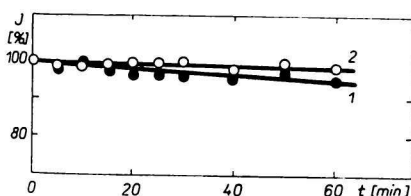
Fig. 6. Dependence of activity decrease of radioactive kryptonate of $AgIO_3$ in distilled water on time.
1. distilled water; 2. distilled water saturated beforehand with $AgIO_3$.

the relative change of indicator activity is followed. The course of titration curves will be given in concrete applications.

The more stable is the given radioactive kryptonate in air and titration milieu and the more easily it liberates the incorporated ^{85}Kr under the influence of adding of titrant solution, the more suitable it is for indicator application in radiochelatometric titrations.

Radioactive kryptonate $AgIO_3$ relatively well keeps the incorporated ^{85}Kr. The dependence of activity decrease on time in air at laboratory conditions is illustrated in Fig. 5.

In Fig. 6, curve 1, can be seen the dependence of activity decrease of radioactive kryptonate $AgIO_3$ in distilled water on time. Curve 2 shows the same dependence for water which was saturated beforehand with non-kryptonated $AgIO_3$.

The dependences mentioned above point to the good stability of radioactive kryptonate $AgIO_3$, especially in a solution saturated beforehand with $AgIO_3$. Another dependence under observation in this material concerned the activity decrease under the influence of adding the excess of titrant solution 10^{-2} M chelatone III. pH value of titration milieu was ~ 9 (set with the help of 0.1 M-NaOH). Each activity value was measured in the same time intervals from the addition of the titrant solution. This dependence is illustrated in Fig. 7, curve 2. From this diagram can be seen that in adding 1 ml of surplus titrant solution 10^{-2} M chelatone
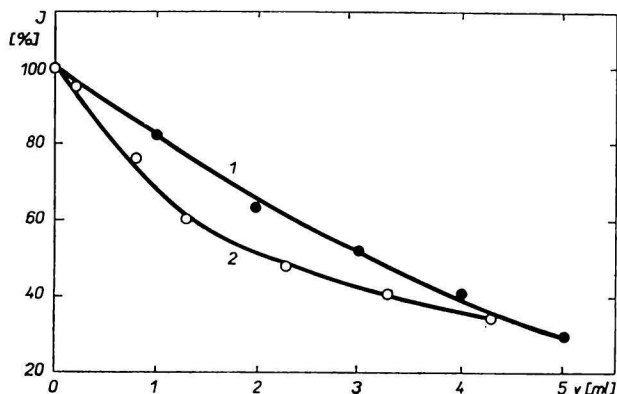

Fig. 7. Dependence of activity decrease of radioactive kryptonate of yttrium oxalate (1) and silver iodate (2) influenced by the addition of 10^{-2} M solution of chelatone III.
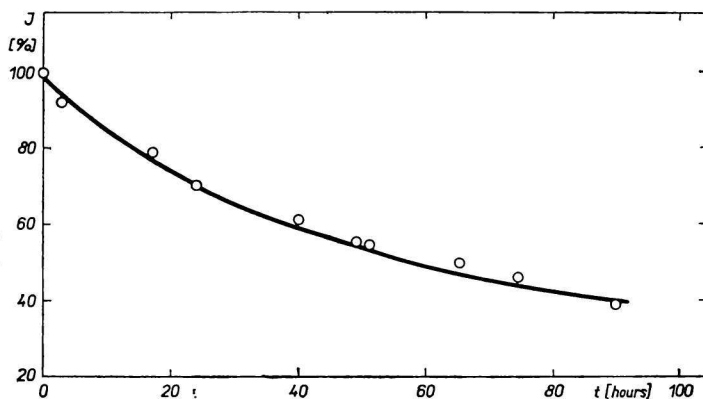

Fig. 8. Dependence of activity decrease of radioactive kryptonate of yttrium oxalate in air at laboratory conditions on time.
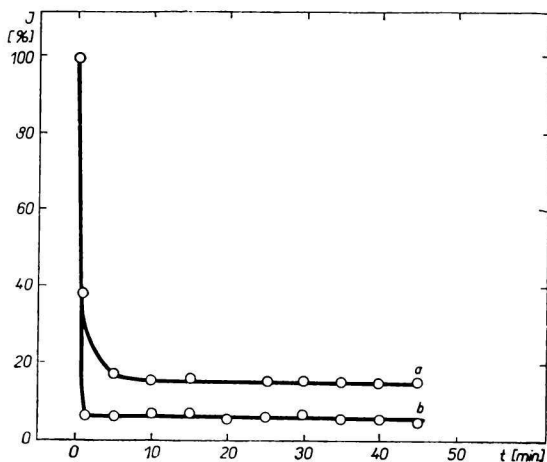
Fig. 9. Dependence of activity decrease of radioactive kryptonate of yttrium oxalate in a solution of tartaric acid and sodium acetate (*a*) and in distilled water (*b*) on time.

III (after exceeding end-point) there occurs an activity decrease of $\sim 20\%$ and in adding 4 ml of surplus titrant solution there is a decrease of $\sim 60\%$. It means that this indicator can very sensitively indicate the end-point in titrations with chelatone (for instance, the determination of Ca^{2+}, Sr^{2+}, Mg^{2+} etc.).

The time dependence stability of radioactive kryptonate of yttrium oxalate prepared by ion bombardment in air is in Fig. 8. It can be seen that after 80 hours the radioactive kryptonate loses $\sim 60\%$ of its initial activity. Its activity in water or in a 1 % solution of tartaric acid and 1 M of sodium acetate (ratio 1 1) rapidly decreases as can be seen from Fig. 9. Curve *a* illustrates the activity decrease of radioactive kryptonate of yttrium oxalate in a solution of tartaric acid and sodium acetate (that is in a milieu where the titration Fe(III) with chelatone III takes place) and curve *b* the activity decrease in distilled water. An equal dependence as in the case of curve *b* was also obtained in distilled water saturated with non krypton-ated yttrium oxalate. The activity decrease of radioactive kryptonate of yttrium oxalate under the influence of adding 10^{-2} M solution of chelatone III is illustrated in Fig. 7, curve *1*. A disadvantage of this radioactive kryptonate is the rapid and considerable activity decrease in air, in water and titration milieu. In spite of this it can be used as indicator in radiochelatometric titrations (e. g. determination of Fe(III)), because it can be relatively easily produced with a high specific activity, which means, that even with a loss of $\sim 80\%$ of initial activity, the remaining activity can sensitively indicate the end-point. The course od dependence of activity decrease under the influence of adding the titrant solution (Fig. 7, curve *1*), is similar to the case of radioactive kryptonate $AgIO_3$, i. e. in adding 4 ml 10^{-2} M solution of chelatone III there occurs a decrease of initial activity of $\sim 60\%$.

Conclusion

The results mentioned in the preceding part of this paper point to further, new possibilities and trends of application of radioactive kryptonates in quantitative chemical analysis.

The methods which have been worked out for the preparation of radioactive

Table 3

A comparison of properties of radioactive kryptonate of $AgIO_3$ and $Y_2(C_2O_4)_3$ from the point of view of their indicator application

Radioactive kryptonate	Methods of preparation	Specific activity obtained [cpm/g]	Suitable for the determination of	Remark
$AgIO_3$	diffusion technique	1 690 000	Ca^{2+}, Sr^{2+}, Mg^{2+}	Very stable, activity in water does not practically change
$AgIO_3$	ion bombardment	—	—	In kryptonation elementary iodinis liberated
$Y_2(C_2O_4)_3 \cdot 9H_2O$	ion bombardment	7 740 000	Fe^{3+}	Small stability. Activity in water decreases up to 90 %, in titration milieu by 80 %

kryptonates make it possible to obtain new radioactive indicators which may be suitably used in volumetric determinations of some materials. Tab. 3 serves to compare properties and suitabilities of application of two radioactive kryptonates prepared in radiochelatometric titrations.

From the Table can be seen that from the radioactive indicators prepared, the most suitable properties for use in volumetric analysis from the point of view of specific activity obtained could have yttrium oxalate. On the other hand, however, in the titration milieu it immediately loses (without the addition of titrant solution) as much as 80 % of its initial activity. For this reason it is less suitable for titration application. Since, however, the initial, attainable, specific activity is considerably high, it can equally well be used as indicator in radiochelatometric titrations as radioactive kryptonate of $AgIO_3$.

Translated by Š. Bachratý

RÁDIOAKTÍVNE KRYPTONÁTY V ODMERNEJ ANALÝZE (I)
RÁDIOAKTÍVNE KRYPTONÁTY —
NOVÉ CHELÁTOMETRICKÉ INDIKÁTORY

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Vypracovala sa metóda na použitie rádioaktívnych kryptonátov ako indikátorov bodu ekvivalencie pri chelátometrických titráciách.

Bod ekvivalencie sa určuje pomocou tuhého rádioaktívneho kryptonátu AB[⁸⁵Kr],

pridávaného do skúmaného roztoku pred začiatkom titrácie. Po prekročení bodu ekvivalencie nadbytok pridaného chelátotvorného činidla reaguje s rádioaktívnym kryptonátom za uvoľnenia rádioaktívneho kryptónu ⁸⁵Kr. Pri titrácii sa môže merať alebo zvyšková aktivita rádioaktívneho kryptonátu, alebo aktivita uvoľneného rádioaktívneho kryptónu. Na tomto princípe možno realizovať rádiochelátometrické titrácie vhodným chelátotvorným činidlom, ktoré kvantitatívne reaguje s iónmi stanovovaného prvku za použitia vhodného rádioaktívneho kryptonátu.

V práci sa uvádzajú princípy metódy titrácie, metódy prípravy rádioaktívnych kryptónovaných indikátorov (AgIO₃ a Y₂(C₂O₄)₃) iónovým bombardovaním a difúznou technikou, ako aj experimentálne výsledky kryptónovania. Ďalej sa uvádza štúdium vlastností pripravených rádioaktívnych kryptonátov z hľadiska ich použitia ako indikátorov pri rádiochelátometrických titráciách, a to predovšetkým ich dekryptonácia na vzduchu pri laboratórnych podmienkach vplyvom titračného prostredia a vplyvom odmerného roztoku chelatonu III.

Z pripravených rádioaktívnych indikátorov najvhodnejšie vlastnosti na použitie v odmernej analýze z hľadiska získanej mernej aktivity má šťaveľan ytritý. Na druhej strane však v titračnom prostredí ihneď stráca (bez prídavku odmerného roztoku) až 80 % východiskovej aktivity, preto je menej vhodný na použitie pri titráciách. Keďže však východisková dosiahnuteľná merná aktivita je značne vysoká, rovnako dobre ho možno využiť vo funkcii indikátora pri rádiochelátometrických titráciách ako rádioaktívny kryptonát AgIO₃.

РАДИОАКТИВНЫЕ КРИПТОНАТЫ В ОБЪЕМНОМ АНАЛИЗЕ (I)
РАДИОАКТИВНЫЕ КРИПТОНАТЫ —
НОВЫЕ ХЕЛАТОМЕТРИЧЕСКИЕ ИНДИКАТОРЫ

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Братислава

Был разработан метод для применения радиоактивных криптонатов в качестве индикаторов эквивалентной точки при хелатометрических титрованиях.

Эквивалентная точка определяется с помощью твердого радиоактивного криптоната AB[⁸⁵Kr], прибавляемого в исследуемый раствор перед началом титрования. После перехода эквивалентной точки избыток прибавленного хелатообразовательного реактива реагирует с радиоактивным криптонатом с выделением радиоактивного криптона ⁸⁵Kr. При титровании может измеряться остаточная активность радиоактивного криптоната или же активность выделенного радиоактивного криптона. На этом принципе можно производить радиохелатометрические титрования подходящим хелатообразовательным реактивом, который количественно реагирует с ионами определяемого элемента с применением подходящего радиоактивного криптоната.

В работе приводятся основы метода титрования и метода приготовления радиоактивных криптонированных индикаторов AgIO₃ и Y₂(C₂O₄)₃ ионной бомбардировкой и диффузией, а также экспериментальные результаты криптонирования. Далее описывается изучение свойств приготовленных радиоактивных криптонатов с точки зрения применения их в качестве индикаторов при радиохелатометрических титрова-

ниях, прежде всего их декриптонирование на воздухе в лабораторных условиях под действием титрационной среды и титрованного раствора Хелатона III.

Из приготовленных радиоактивных индикаторов лучше всего подходит для применения в объемном анализе, с точки зрения полученной удельной активности, щавелевокислый иттрий, который, однако, в титрационной среде сразу же теряет (без прибавления титрованного раствора) до 80 % своей первоначальной активности. Поэтому он менее пригоден для титрования. Но поскольку первоначально достижимая удельная активность достаточно большая, можно его успешно применить в качестве индикатора при радиохелатометрических титрованиях как радиоактивный криптонат $AgIO_3$.

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