

Specific Separation and Preconcentration of Trace Amounts of Gallium in Water and Rice Samples utilizing Cloud Point Extraction and Determination by Inductively Coupled Plasma-Atomic Emission Spectrometry

Basuka Widodo¹, Suchilo Diranto²Department of Neonatology, Universitas Brawijaya, Jawa Timur 65145, Indonesia^{1,2}

Abstract— In the present investigation, a cloud-point extraction process utilizing non-ionic surfactant Triton X-114 for a particular extraction of gallium from watery arrangements was created. The strategy depends on the unpredictable development of Ga (III) with N, N' - bis (salicylidene)- 1, 2-phenylenediamine (salophen) as a chelating operator in cradle media of pH 5. After stage partition and weakening of the surfactant-rich stage with 0.2 mL of an (80-20) propanol-water blend containing 0.02 mL HNO₃, the improved analyte was dictated by inductively coupled plasma-nuclear discharge spectrometry (ICP-AES). The factors influencing the complexation and extraction steps were streamlined. Under the ideal conditions (for example, 7.5×10^{-5} mol L⁻¹ salophen, 0.5% (v/v) Triton X-114, 45°C balance temperature, brooding time 15 min) the alignment chart was direct in the scope of 20–120 ng mL⁻¹ with a recognition point of confinement of 1.5 ng mL⁻¹. The exactness (R.S.D. %) for five imitate conclusions at 60 ng mL⁻¹ of Ga (III) was superior to 4%. As such, the preconcentration factor was 22.2. Under the nearness of remote particles, no noteworthy obstruction was watched. At long last, the proposed technique was used effectively for the assurance of gallium in water and rice tests.

Keywords— Cloud point extraction, Gallium, Inductively coupled plasma nuclear emanation spectrometry, Salophen, Rice.

1. Introduction

Albeit, a portion of the inorganic cations, (for example, calcium) go about as fundamental micronutrients in the body and their lack can prompt different ailments [1] some cations have no health benefit for people as well as being profoundly poisonous and risky. On account of their un-degradability and aggregation in the human body, they can eventuate an excessive number of sicknesses, for example, malignancy, kidney and liver harm, male pattern baldness, hearing misfortune and extreme dangerous impacts [2]. Gallium is a perfect case for this sort of cation. The market interest for gallium items has step by step expanded during the previous decade. Gallium salts are utilized in medication as tumor-examining [3] and antitumoral specialists [4]. The significant use of Ga is in the semiconductor business [5-7]. Lately, it has been utilized in numerous applications, for example, microwave handsets, laser diodes in minimized plates and different gadgets [8]. From a natural perspective, the expanding significance and utilization of mixes, for example, gallium arsenide in the semiconductor business, has suggested the conversation starter of its lethality and potential peril when it is suspended in the mechanical climate [6, 9-12]. These are purposes behind creating delicate investigative strategies for the assurance of gallium. As of late, a few methods have been accounted for the assurance of gallium in various kinds of frameworks including, spectrophotometry [13], subsidiary spectrophotometry [14], AAS [15,16], ICP-AES [17,18], ICP-MS [19], X-beam fluorescence spectrometry [20], electroanalytical systems, for example, voltammetry [21,22], polarography [23], chronopotentiometry [24,25], particle specific cathode [26], coulometric [27] and PVC-layer mass optode [28]. In practically every one of these techniques, particularly in spectrometry strategies, an earlier division and preconcentration of

the analyte are fundamental for following gallium assurance, to improve the exactness, precision and to conquer network and reagent impedances. Dissolvable extraction is one of the far-reaching techniques, which was utilized for recuperating gallium from weakening sources [19-34]. Additionally, other extraction and preconcentration procedures, for example, strong stage extraction [35,36], extraction by microemulsions [37], particle trade [38,39], supercritical liquid extraction (SFE) [8,9] and layer [40] have been utilized for gallium particles.

In the most recent decade, an expanding interest is indicated everywhere throughout the world in creating surfactant-based strategies in all fields of scientific science. One of these techniques is called cloud point extraction (CPE) which depends on the obfuscating marvel of surfactant arrangements over a specific temperature and acquiring a concentrated period of hydrophobic solutes [41,42].

Salophen, which is one of the most famous even tetradentate ligands, structures buildings with different metal particles [43]. The structure of salophen is portrayed in Figure 1. In writing, there is no report on the mind-boggling development of this reagent with Ga^{3+} particle. Along these lines to get data about the stoichiometry and strength of this perplexing, a few investigations were completed.

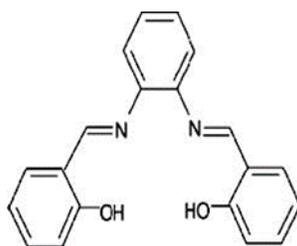


Fig 1. Salophen's structure.

In this work after primer spectrophotometric thinks about on the perplexing development of salophen with $Ga(III)$, we report a profoundly particular, delicate and exact technique dependent on cloud point extraction combined with ICP-AES for specific assurance of gallium at $\mu g L^{-1}$ levels, utilizing salophen as a chelating operator, in water and rice tests. It is essential to state neither Spectrophotometric ponders on the mind-boggling development of salophen with Ga^{3+} particle nor the cloud point systems have been accounted for in the writing as being utilized for gallium assurance both are accounted for just because.

2. Experimental

2.1 Materials

Every one of the synthetics and reagents was of the most elevated virtue accessible and utilized as got. The nonionic surfactant Triton X-114 was from Sigma (St. Louis, MO, USA). Standard gallium arrangements were set up by sequential weakening of a 1000 mg L^{-1} standard (Fluka, Gallium Standard for AAS) with water. The pH was balanced with the support arrangements CH_3COONa/HCl , for pH 3– 6 and $KH_2PO_4/NaOH$, for pH 7–8. A stock arrangement of salophen (1×10^{-3} mol L^{-1}) was set up by dissolving a suitable measure of this ligand in methanol.

2.2 Blend of *N, N'* - bis (salicylidene)- 1, 2-phenylenediamine

An ethanol arrangement (10 mL) containing 1,2-phenylenediamine (approx 3 g) was moved into a 150 mL brisk fit round-bottomed cup, fitted with a speedy fit condenser and afterward salicylaldehyde (approx 5 mL) was included drop insightful. The blend was refluxed for 10 h, sifted and recrystallized twice in ethanol [43].

3. Devices

A Perkin-Elmer model lambda 25 twofold pillar UV–Vis spectrophotometer with a 1 cm quartz cells was utilized for recording all spectra and absorbance estimations. Concurrent inductively coupled plasma optical emanation spectrometer (ICP-AES, Varian Vista-PRO, Mulgrave, Australia) coupled to a V-groove nebulizer and outfitted with a charge-coupled gadget (CCD) indicator was utilized for estimation of Ga in the surfactant-rich stage. A Metrohm 827 pH meter furnished with a Metrohm glass terminal was utilized for pH estimations. A Julabo model F12 Experimental

4. Mechanical assembly

A Perkin-Elmer model lambda 25 twofold bar UV–Vis spectrophotometer with a 1 cm quartz cells was utilized for recording all spectra and absorbance estimations. Synchronous inductively coupled plasma optical discharge spectrometer (ICP-AES, Varian Vista-PRO, Mulgrave, Australia) coupled to a V-groove nebulizer and outfitted with a charge-coupled gadget (CCD) finder was utilized for estimation of Ga in the surfactant-rich stage. A Metrohm 827 pH meter outfitted with a Metrohm glass anode was utilized for pH estimations. A Julabo model F12 water shower (Germany) with $\pm 0.1^\circ\text{C}$ temperature control was utilized for cloud point extraction tests and a rotator with 10 mL adjusted axis tubes (Superior, Germany) was used to quicken the stage partition process.

5. Methodology

An aliquot of Ga (III) standard arrangement was moved to a 10 mL rotator tube; 0.75 mL of 1×10^{-4} mol L⁻¹ salophen arrangement and 1 mL of a cushion arrangement (0.1 mol L⁻¹, pH 5) were included. The blend was left for 15 min to finish complex development before the expansion of 0.5 mL of 5% (v/v) of the Triton X-114 arrangement. At that point, the arrangement was sufficient (10 mL) with doubly refined water. Therefore, the example was shaken and left to remain in a thermostatted water shower for 15 min at 45°C. Partition of the watery and surfactant-rich stage was quickened by centrifugation for 7 min at 3500 rpm. After cooling in a salt-ice shower, the surfactant-rich stage got goeey. At that point, the fluid stage was deliberately evacuated with a pipette and 0.2 mL of an 80:20 methanol-water blend containing 0.02 mL HNO₃ was added to the surfactant-rich stage to decrease its thickness and increment the example volume for the ICP-AES estimation. At last, the examples were brought into the plasma with a peristaltic siphon. The power was estimated at 294.363 nm as the chose outflow wavelength for gallium and the focus was resolved to utilize the relapse condition given in Table 3.

6. Examination of Water and Rice Samples

Tap and seawater tests were gathered from Tehran and the Caspian Sea (Zibakenar) in Iran, individually. Each example was separated utilizing a 0.45 μm PTFE channel and changed under estimated pH 5 by including NaOH\HNO₃. An aliquot of the example (7 mL) first straightforwardly and afterward spiked with the proper measure of Ga³⁺ was exposed to the cloud-point extraction system as depicted previously.

The pretreatment of rice tests was done by the writing [44]. The rice test was first dried at 110 °C and afterward grounded utilizing an agate mortar. At that point, 0.5 g of the example was gauged and moved into

a measuring utensil. 9 mL of concentrated HNO₃ was included and the blend was kept medium-term. At that point, the substance of the measuring utensil was vanished close to dryness (at about 130°C) on a hot plate. In the wake of cooling to room temperature, 3 mL of concentrated HNO₃ and 2 mL of concentrated HClO₄ were included in the measuring glass and again it was vanished close to dryness, weakened to volume with refined water in a volumetric carafe (25.0mL). 7mL of this arrangement exposed to cloud point extraction as portrayed water tests.

7. Results and exchange

7.1 Primer Complexation Studies

To acquire some data about the stoichiometry and steadiness of Ga (III)- salophen complex, in primer examinations, the complexation of salophen with this cation was explored spectrophotometrically in methanol dissolvable. As such, an answer containing a steady convergence of salophen (7.0×10^{-5} mol L⁻¹) was titrated with a methanol arrangement of Ga (III). The came about the range is given in Figure 2. As it is self-evident, an expansion in the ingestion band at 393 nm and a lessening in the assimilation band at 263 nm were obvious as the centralization of the complex is expanded and the grouping of a free ligand is diminished. The retention information at 393 nm was utilized for the stoichiometry investigation of complex (Figure 3). As can be seen from this figure, the absorbance-mole proportion plot uncovers particular intonation at metal to ligand proportion of 1:1, demonstrating that the came about complex has 1:1 (metal-to-ligand) stoichiometry. The development consistent (Log K) of the subsequent complex was assessed as 5.4, by PC fitting of the absorbance-mole proportion information utilizing the KINFIT program [45] at a similar wavelength.

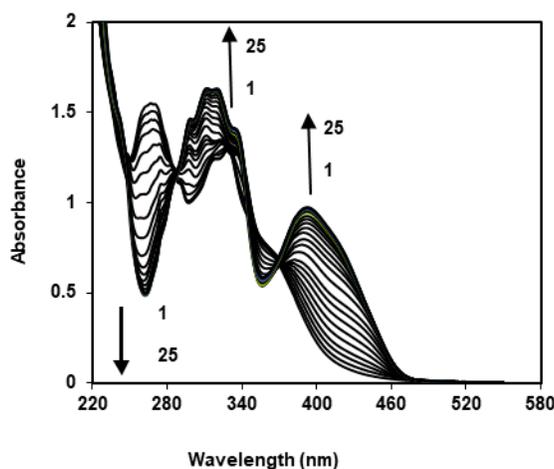


Fig 2. Absorption spectra of salophen (7.0×10^{-5} M) in methanol solution at 25°C in the presence of varying concentration of Ga(III) ion (mol L⁻¹): (1) 0.0×10^{-5} , (2) 0.53×10^{-6} , (3) 1.06×10^{-5} , (4) 1.60×10^{-5} , (5) 2.14×10^{-5} , (6) 2.67×10^{-5} , (7) 3.21×10^{-5} , (8) 3.74×10^{-5} , (9) 4.28×10^{-5} , (10) 4.81×10^{-5} , (11) 5.34×10^{-5} , (12) 5.88×10^{-5} , (13) 6.41×10^{-5} , (14) 6.95×10^{-5} , (15) 7.49×10^{-5} , (16) 8.02×10^{-5} , (17) 8.56×10^{-5} , (18) 9.09×10^{-5} , (19) 9.63×10^{-5} , (20) 1.02×10^{-4} , (21) 1.07×10^{-4} , (22) 1.12×10^{-4} , (23) 1.18×10^{-4} , (24) 1.28×10^{-4} and (25) 1.82×10^{-4} .

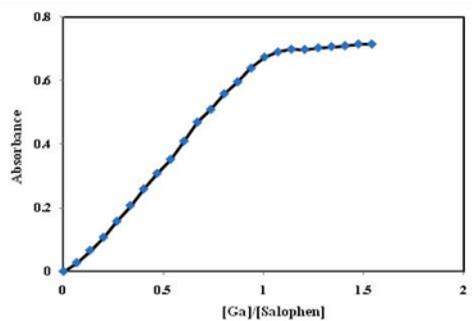


Fig 3. Mole ratio plot of complexation of salophen with Ga (III) in methanol solution at 393 nm.

7.2 Strategy Development

From the outset and before examination of measures and genuine examples, various factors, which influence the power of the nuclear outflow sign of removed gallium in ICP-AES, were upgraded utilizing a standard arrangement of this component. The instrumental parameters (for example generator control, generator recurrence, plasma gas stream rate, and assistant stream rate, nebulizer pressure, seeing tallness, steadiness time and wavelength) are given in Table 1.

Parameter	Value
RF generator power (W)	1400
Frequency of RF generator (MHz)	40
Plasma gas flow rate (L min ⁻¹)	14
Auxiliary gas (L min ⁻¹)	1.5
Nebulizer pressure (kPa)	200
Viewing height (mm)	8
Stability time (s)	38
Wavelength (nm)	294.363

Table 1. Operation parameters of ICP-AES

7.3 Streamlining of the System

Impact of pH: The detachment of metal particles by the cloud point technique includes the earlier development of a complex with adequate hydrophobicity which at that point can be removed by the little volume of the surfactant-rich stage; in this way acquiring the ideal preconcentration. pH assumes a special job in the metal-chelate development and consequent extraction. Figure 4 shows the impact of pH on the emanation force of the gallium at 294.363nm. As can be seen, at pH 5 greatest extraction productivity was

acquired. Thus, this pH was picked for the resulting tests.

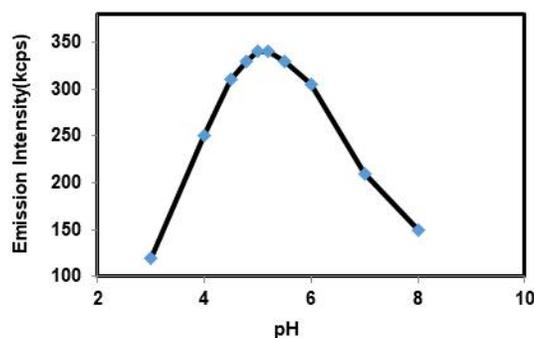


Fig 4. Effect of pH on the emission intensity of gallium after extraction. Extraction Condition: Ga (III) 60 ng mL⁻¹; salophen 7.5×10⁻⁶ mol L⁻¹; Triton X-114 0.5% (v/v); equilibrium temperature 45°C for 15 min extraction time; centrifugation time 7 min in 3500 rpm.

Impact of salophen focus: The extraction proficiency as an element of the salophen fixation has appeared in Figure 5. For this investigation, 10 mL of an answer containing 600 ng Ga (III) with different measures of salophen ((0.25-1.4) ×10⁻⁵ mol L⁻¹) was exposed to the CPE strategy. The outcomes uncovered that the extraction recuperation increments by expanding salophen focus up to 7.5×10⁻⁶ mol L⁻¹ and remained almost consistent at higher fixations. Subsequently, this focus was chosen as an ideal worth.

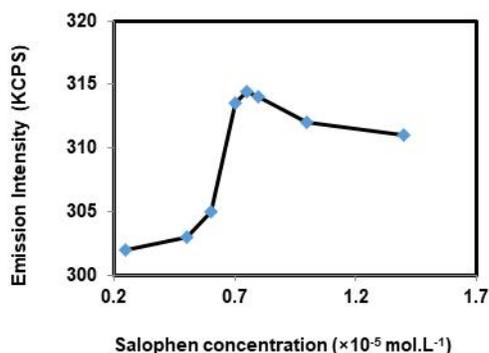


Fig 5. Effect of reagent concentration on the emission intensity of gallium after extraction. Ga (III)60 ng mL⁻¹; Triton X-114 0.5% (v/v); extraction condition as described in text.

Impact of Triton X-114 focus: The measure of nonionic surfactant Triton X-114 is basic since it influences the quantitative extraction of analyte and thusly strategy affectability [41]. Additionally, the high thickness of the surfactant-rich stage encourages stage partition by centrifugation [46]. The impact of Triton X-114 fixation on the outflow power of the separated stage was examined in the scope of 0.1-1% (v/v). As found in Figure 6 the convergence of 0.5% (v/v) was picked as ideal for the quantitative recuperation of the complex. At lower fixations, the extraction effectiveness of the complex is low, presumably as a result of the insufficiency of the congregations to ensnare the hydrophobic complex quantitatively.

Impacts of the equilibration temperature and time: The equilibration temperature over the basic point temperature (CPT) of Triton X-114 and the brooding time were the parameters improved straightaway. It is alluring to utilize the most limited hatching time and the least conceivable equilibration temperature, which bargains with the culmination of the response and the effective partition of stages. The reliance of outflow power upon equilibration and hatching times was considered inside the scope of 5-30 min. Time of 15 min was picked as the ideal time for the fruition of the obfuscating procedure and analyte extraction. It was additionally seen that a temperature of 45°C is adequate for the most extreme recuperation of the analyte.

Impact of centrifugation time: Centrifugation time barely ever influences micelle development yet quickens stage detachment in a similar sense as in the traditional partition of a hasten from its unique watery condition [40]. An axis time of 7 min was chosen as ideal, as complete division happened inside this time and no apparent upgrades were watched for longer periods.

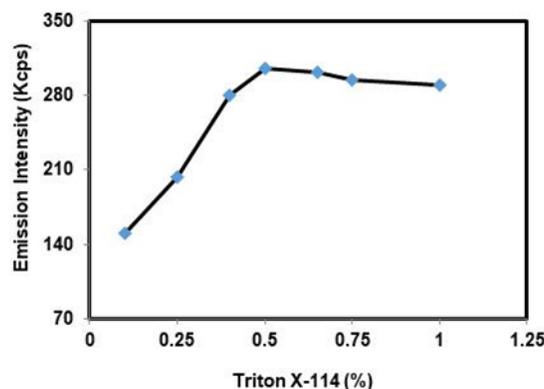


Fig 6. Effect of Triton X-114 on the emission intensity of gallium after extraction. Ga (III) 60 ng mL⁻¹; salophen 7.5×10⁻⁶ mol L⁻¹; extraction condition as described in the text.

Impacts of included electrolyte: The cloud purpose of micellar arrangements can be constrained by the expansion of salts, alcohols, non-ionic surfactants and some natural mixes (salting-out impacts). Until this point in time, the majority of the examinations directed have indicated that ionic quality has no considerable impact on extraction productivity [46]. It was seen that the expansion of inorganic salts including NaCl, KNO₃, and Na₂SO₄ in the scope of 0–2 mol L⁻¹ had no critical impact on the cloud point extraction effectiveness.

7.4 Selectivity Studies

On account of the high selectivity gave by inductively coupled plasma spectrometry, the main impedances examined were those identified with the preconcentration step, and therefore influencing extraction effectiveness. In the wake of choosing the ideal conditions, to do this examination, a progression of arrangements (10 mL) containing 60 ng mL⁻¹ of Ga³⁺ and various convergences of meddling particles were exposed to the total system. The outcomes uncovered that the Ga³⁺ recuperation was practically quantitative within the sight of different particles with resistance limits that appeared in Table 2. As far as possible was characterized as the centralization of included particle causing under ±5% relative blunder. As can be seen, a few bivalent and some trivalent cations can meddle with the assurance of Ga³⁺ at an alternate proportion. Note that impedances by remote cations just influence the salophen focus because the recognition step is exceptionally specific; along these lines, any ligand misfortune can be maintained a strategic distance from by expanding its fixation. A large portion of the Interfering cations can likewise be dispensed with by the proper weakening of the example, or the expansion of KSCN, KI, and trisodium citrate, as evacuating and covering operators. It is obvious that among the meddling particles which were tried; soluble base, basic earth components, and anions, (for example, nitrate, sulfate, and others) don't have any huge impacts on the extraction proficiency.

7.5 Expository Characteristics

Table 3 condenses the expository qualities of the enhanced strategy, including relapse condition, straight range, and breaking point of discovery (LOD), reproducibility and preconcentration factor. The point of confinement of location which was characterized as $CL = 3sB/m$ (where CL, sB, and m are the farthest point of discovery, the standard deviation of the clear, and incline of the alignment diagram, separately), was 1.5 ng mL^{-1} . Since the measure of gallium in 10 mL of the example arrangement is estimated after preconcentration by CPE in the last volume of 0.45 mL (0.25 mL surfactant-rich stage + 0.2 mL diluents), the arrangement is thought by a factor of 22.2. The relative standard deviation (R.S.D.) for five recreate estimations of 60 ng mL^{-1} of gallium was 4.0%.

7.6 Validation and Application

To approve the proposed technique, it was applied to the assurance of gallium in faucet water and seawater tests. The outcomes have appeared in Table 4. The mean recuperations for the expansion of various convergences of gallium to water tests were in the scope of 97.5-108%. The outcomes indicated that the proposed strategy could be effectively applied to the assurance of following measures of gallium in water tests. To evaluate the pertinence of the technique to other genuine examples, it was applied to the assurance of gallium in rice. For this situation, 7 mL of rice test was first preconcentrated and afterward, its gallium was resolved utilizing the standard expansion strategy. The normal substance of Ga (III) in rice was resolved to be 162 ng/g with a normal recuperation of 95%.

8. Conclusion

Spectrophotometric thinks about on salophen showed that it shapes a complex with Ga (III) having a stoichiometry of 1:1. In view of this perplexing arrangement, a cloud point extraction strategy combined with ICP-AES was created for the specific partition, preconcentration, and assurance of this cation at $\mu\text{g L}^{-1}$ levels. The proposed technique gives a decent reproducibility and gives an exact, exceptionally delicate and particular system for the assurance of gallium that applies to the water and rice tests containing follow measures of this component. It is critical to state neither Spectrophotometric thinks about on the intricate arrangement of salophen with Ga^{3+} particle nor the cloud point strategies have been accounted for in the writing as being utilized for gallium assurance, truth be told, both are accounted for just because.

9. References

- [1] M. R. Jalali Sarvestani, R. Ahmadi, *Int. J. New. Chem.*, 4, 400 (2018).
- [2] M. R. Jalali Sarvestani, R. Ahmadi, *Int. J. New. Chem.*, 5, 409 (2018).
- [3] M. D. S. Nomura, M. D. Y. Watanabe, M. D. N. Otsuka, et al. *Am. J. Kidney. Dis.*, 27, 204 (1996).
- [4] A. V. Rudnev, L. S. Foteeva, C. Kowol, *J. Inorg. Biochem.*, 100, 1819 (2006).
- [5] S. Kayasth, N. Raje, T. P. S. Asari, et al. *Anal. Chim. Acta.*, 370, 91 (1998).

- [6] D. Kara, A. Fisher, M. Foulkes, et al. *Spectrochimica. Acta. Part A.*, 75, 361 (2010).
- [7] M. D. Prat, R. Compañó, M. Granados, et al. *J. Chromatogr A.*, 746, 239 (1996).
- [8] W. L. Chou, C. T. Wang, K. C. Yang, et al. *J. Hazard. Mater.*, 160, 6 (2008).
- [9] C. C. Wu, H. M. Liu, *J. Hazard. Mater.*, 163, 1239 (2009).
- [10] A. Tanaka, *Toxicol. Appl. Pharmacol.*, 198, 405 (2004).
- [12] T. A. Gondre-Lewis, C. B. Hartmann, R. E. Caffrey, et al. *Int. Immuno. pharmacol.*, 3, 403 (2003).
- [13] S. J. S. Flora, P. Kumar, G. M. Kannan, *Toxicol. Lett.*, 94, 103 (1998).
- [14] A. Huseyinli, R. Aliyeva, *Anal. Sci.*, 17, i1683 (2001).
- [15] X. Guo, M. Hoashi, R. R. Brooks, et al. *Anal. Chim. Acta.*, 259, 289 (1992).
- [16] F. Takekawa, R. Kuroda, *Talanta.*, 35, 737 (1988).
- [17] R. Dumortier, E. Rodil, M. E. Weber, et al. *Water. Res.*, 38, 1745 (2004).
- [18] K. Satyanarayana, K. Subramaniam, A. V. Raghunath, *Analyst.*, 121, 825 (1996).
- [19] M. Martin, F. X. Olivier, *Anal. Chem.*, 70, 2639 (1998).
- [20] M. S. Carvalho, J. A. Medeiros, A. W. Nobrega, et al. *Talanta.*, 42, 45 (1995).
- [21] E. D. Moorhead, P. H. Davis, *Anal. Chem.*, 47, 622 (1975).
- [22] M. J. G. González, O. D. Renedo, M. A. A. Lomillo, et al. *Talanta.*, 62, 457 (2004).
- [23] H. d. Sommer, F. Umland, *Anal. Chem.*, 301, 203 (1980).
- [24] X. Zhao, Z. Zhang, W. Li, et al. *Anal. Chim. Acta.*, 318, 181 (1996).
- [25] E. D. Moorhead, N. H. A. Furman, *Anal. Chem.*, 32, 1507 (1960).
- [26] S. K. Mohamed, *Anal. Chim. Acta.*, 562, 204 (2006).
- [27] H. S. Sharma, T. K. Bhardwaj, P. C. Jain, et al. *Talanta*, 71, 1263 (2007).
- [28] A. Safavi, M. A. Sadeghi, *Talanta*, 71, 339 (2007).
- [29] J. Jayachandran, P. Dhadke, *Hydrometallurgy.*, 50, 117 (1998).
- [30] G. V. K. Puvvada, *Hydrometallurgy.*, 52, 9 (1999).

- [31] M. S. Lee, J. G. Ahn, E. C. Lee, *Hydrometallurgy.*, 63, 269 (2002).
- [32] T. Kekesi, *Hydrometallurgy.*, 88, 170 (2007).
- [33] T. H. Bokhari, A. Mushtaq, I. U. Khan, *Appl. Radiat. Isot.*, 67, 100 (2009).
- [34] T. Kinoshita, S. Akita, S. Nii, et al. *Sep. Purif. Technol.*, 37, 127 (2004).
- [35] N. Hatori, H. Imura, A. Ohashi, et al. *Anal. Sci.*, 24, 1637, (2008).
- [36] U. Divrikli, M. Soylak, L. Elci, *Anal. Lett.*, 36, 839 (2003).
- [37] T. N. Castro Dantas, M. H. Lucena Neto, A. A. Dantas Neto, *Talanta.*, 56, 1089 (2002).
- [38] C. R. Rao, *Anal. Chim. Acta.*, 318, 113 (1995).
- [39] A. W. Trochimczuk, S. Czerwijska, *React. Funct. Polym.*, 63, 215 (2005).
- [40] K. Kondo, Y. Yamamoto, M. Matsumoto, *J. Membr. Sci.*, 137, 9 (1997).
- [41] A. Beiraghi, S. Babae, *Anal. Chim. Acta.*, 607, 183 (2008).
- [42] S. Babae, A. Beiraghi, *Anal. Chim. Acta.*, 662, 9 (2010).
- [43] M. Joshaghani, M. B. Gholivand, F. Ahmadi, *Spectrochim. Acta. A.*, 70, 1073 (2008).
- [44] D. M. Boghaei, S. J. S. Sabounchei, S. Rayati, *Synth. React. Inorg. Met-org. Chem.*, 30, 1535 (2000).
- [45] T. Şerife, L. Aysel, *Microchim. Acta.*, 164, 471 (2009).
- [46] J. L. Dye, V. A. Nicely, *J. chem. Educ.*, 48, 443 (1971).
- [47] A. Niazi, T. Momeni-Isfahani, Z. Ahmari, *J. Hazard. Mater.*, 165, 1200 (2009).



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