

N-n-HEPTYLANILINE AS A NEW REAGENT FOR THE LIQUID-LIQUID EXTRACTION OF THALLIUM (III)

Abstract

The present study is concerned with the simple solvent extraction of thallium(III) from mineral acid media with N-n-heptylaniline in xylene is reported in this paper. Thallium(III) was back extracted with acetate buffer (pH = 4.63). The effect of acid and extractant media, role of various diluents, stripping agents, loading capacity, aqueous to organic volume ratio, equilibrium time, temperature effect on extraction of thallium(III) has been studied. The stoichiometry of extracted species was determined on the basis of slope analysis method. The method was free from interference of large number of cations and anions. The method was used for selective extraction of thallium(III) from its binary mixture. The proposed method was used for the analysis of synthetic mixtures and real sample like alloy. It is rapid and selective method.

Keywords: N-n-heptylaniline, mineral acid media, synthetic mixtures, alloy analysis.

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I. INTRODUCTION

The English chemist William Crookes discovered thallium in 1861, and C Lamy, a French scientist, synthesized metallic thallium for the first time in 1862 [1]. It was commonly used to treat tuberculosis, malaria, and venereal disorders. It was also administered to children to induce hair loss as a side effect of treating scalp ringworm [2]. It is bluish white, inelastic, soft and easily fusible heavy metal having common oxidation states +1 (thallous) and +3 (thallic). It is present in cadmium(II), lead(II), zinc(II) or indium(III) compounds as a trace constituent hence extraction and separation is important [3, 4].

Pure thallium is found on the earth's crust in trace amount. It is malleable, soft and bluish-white metal. Thallium is odourless and tasteless in its pure form. When thallium is combined with other substances, it exhibits a colorless to white or yellow appearance [5]. Its persistence in the environment is attributed to its inability to undergo decomposition into simpler substances [6]. Thallium is characterized as a trace element with a relative atomic mass of 204.37 and an atomic number of 81. Due to its density, which is measured at 11.83 g/cm³, it is categorized as a heavy metal [7].

It mainly occurs in sulphur containing ores [8]. In the activation of enzymes Tl (I) is known to replace potassium ions [9]. With metals namely antimony, silver and lead thallium readily forms alloys. The commercial cost of thallium is more than \$ 2000 per kg. The contamination of the environment with thallium results from coal combustion, nonferrous amines and cement plants [10].

These days, thallium is utilized in the production of low temperature thermometers, artist's paints, counterfeit jewelry, electronic components, semiconductor materials, optical lenses, alloys, and gamma radiation detecting apparatus. In the visualisation of tumors and in myocardial imaging thallium is used as a radiological contrast agent. The main source of exposure to thallium in the general population is due to atmospheric pollution e.g. coal-burning power plants [11].

The comprehensive index in the 1995 edition of 'Chemical Abstracts' catalogs more than 150 applications and potential uses of thallium and its compounds, dating back to the early 20th century. Thallium salts had widespread applications, including the treatment of syphilis since 1883 and the alleviation of night sweats in tuberculosis patients since 1898 [12]. Starting in 1920, thallium salts found utility as rodent poisons and subsequently as insecticides, maintaining this role as the primary use of the element for the next 45 years [13]. Placenta freely crosses thallium and produces congenital abnormalities as well as fatal death [14]. The toxicity is due to destructive effects on enzyme systems in the body.

By considering all these, it is interesting to develop a extraction and separation method for thallium.

II. SUMMARY OF LIQUID-LIQUID EXTRACTION METHODS FOR THALLIUM(III) AND THALLIUM(I)

The utilization of HMWA (High Molecular Weight Amine) has been examined for the solvent extraction of thallium(III). A swift and uncomplicated method was employed to

extract and separate trace amounts of thallium(III) and indium(III) from chloride and iodide solutions at various concentrations of sulfuric acid using trioctylamine [15]. Thallium(III) was efficiently and quantitatively extracted from 2 M hydrobromic acid using N-benzylaniline [16]. Investigation into the extraction of trace amounts of thallium(III) in the presence and absence of macro amounts of gallium(III), indium(III), and iron(III) with solutions of trioctylamine and aliquat 336 revealed co-extraction and extraction suppression occurring in the studied system [17]. A straightforward solvent extraction study for thallium, based on the extraction of thallium forming chlorocomplexes, was conducted using tribenzylamine, achieving a thallium recovery of approximately 95% [18]. N-n-octylaniline in benzene was employed for the liquid-liquid extraction of thallium(III) from aqueous chloride media. For the quantitative extraction of thallium(III), a relatively high concentration of this extractant (0.10 M) was required, and interference from bismuth(III), citrate, ascorbate, thiourea, and thiocyanate was observed [19]. Primary amine, n-octylaniline dissolved in toluene, has been recognized as an effective extractant for thallium(III) when utilizing a salicylate medium [20].

X. Zhang et al. conducted the extraction of thallium(III) and thallium(I) from chloride media in their study [21]. CA-12 was identified as an effective extractant for the separation of Tl(I) and Ga(III), as well as Tl(I) and In(III) [22]. Thallium(I) was successfully extracted using hexanoic acid, a monocarboxylic acid that can be dissolved in benzene, 4-methyl-2-pentanone, chloroform, or nitrobenzene [23]. Organophosphorus compounds have proven to be useful for thallium(III) extraction, with the neutral extractant tri-n-octylphosphine oxide (cyanex 921) demonstrating the ability to extract thallium(III) into toluene at pH 2.0 [24]. This method was extended for the mutual separation of gallium(III) and indium(III) from thallium(III) [25]. Thallium(III) was effectively extracted from a sodium salicylate solution ranging from 1.3×10^{-3} to 3.1×10^{-3} M using 10 mL of 45% tris(2-ethylhexyl) phosphate [26]. Additionally, the extraction of thallium(III) from hydrochloric acid solutions was studied using trioctylphosphine oxide and tributyl phosphate [27, 28]. TOPO (tri-n-octylphosphine oxide) exhibited a higher extraction efficiency for thallium(III) compared to tributyl phosphate. Furthermore, the extraction coefficient of thallium(III) with trioctylamine was found to increase with rising acid concentration [29, 30]. A thermodynamic study of the liquid-liquid extraction of thallium(I) was conducted using diethylhexylmonothiophosphoric acid (D2EHMPTA) [31, 32] and di(2-ethylhexyl)dithiophosphoric acid [33] in the organic phase at temperatures ranging from 278.15 to 303.15 K. A method involving crown ether was employed for the separation of thallium(I) from thallium(III) [34]. Finally, the separation of gallium, indium, and thallium was achieved through extraction with n-octylaniline in chloroform [35].

Thallium(III) was successfully separated from geological material using methyl isobutyl ketone (MIBK) in hydrobromic acid [36, 37]. An alternative method involved the extraction of thallium(III) from 10 M hydrochloric acid media using isoamyl acetate [38]. LIX 63 was employed to extract thallium(III) from 0.1-10 M hydrochloric acid media, revealing that the distribution coefficient of thallium increases with rising temperature [39]. This extraction process was found to be dispersion-free [40, 41]. Investigations into the liquid-liquid extraction of thallium(III) from NaCl-H₂SO₄ solution in butyl acetate were conducted using PVDF (polyvinylidene fluoride, hydrophobic) and polypropylene HF (hollow fiber) [42-45]. It's worth noting that Fe(III) was partially co-extracted with

thallium(III) [46]. Another study involved the rapid liquid-liquid extraction of thallium(III) from succinate media using 2-octylaminopyridine in chloroform as an extractant [47].

The thermal decomposition of metal complexes extracted with high molecular weight amines was investigated [48]. Thallium-201 was effectively separated from lead-201 using n-benzylaniline [49]. A thorough examination of the liquid-liquid extraction of indium and thallium from chloride media using the resin ion exchange method was conducted [50]. The solvent extraction behavior of gallium(III), indium(III), and thallium(III) with cyanex-925 (Bis-2,4,4-trimethylpentyl-n-octyl phosphine oxide) was studied [51]. Kuchekar et al. performed a reverse phase separation of gallium(III), indium(III), and thallium(III) [52]. An innovative method was developed for the selective extraction and chromatographic separation of thallium(III) using N-n-octylaniline as a stationary phase on silica gel [53]. A new, efficient procedure for the simultaneous preconcentration of ultratrace amounts of gold and thallium was established using an ion pair-based ultrasound-assisted emulsification-solidified floating organic drop microextraction approach, followed by graphite furnace atomic absorption spectrometry determination [54]. Additionally, methylene blue has been proposed as a new analytical reagent for the catalytic spectrophotometric determination of thallium(I) [55]. The complexometric determination of thallium(III) using bromide as a masking agent and silver(I) as a demasking agent was also explored [56].

Under pseudo three-phase equilibrium, a method for separating Tl(I) and Tl(III) in the presence of other heavy metals has been established [57].

In this study, we suggest a straightforward and fast thallium(III) extraction method. We examined the selective and quantitative extraction of thallium(III) using N-n-heptylaniline in xylene. Several parameters, including reagent concentration, acid concentration, loading, volume ratio, contact time, and temperature, were systematically investigated. The nature of the extracted species was predicted by utilizing a $\log[D]$ vs. $\log[C]$ plot. It was determined that numerous cations and anions do not interfere with the process. This proposed method was effectively applied to separate thallium(III) from binary, ternary mixtures, and alloys.

III. EXPERIMENTAL

1. Instrumentation: Elico pH meter model (LI-120) was used to read pH of the solution. Digital balance was used for the weighing purpose.

2. Reagent and Solution

- **Thallium (III) Solution:** Stock solution of thallium(I) was made by dissolving an adequate quantity of its nitrate salt in very dilute nitric acid. Further thallium(I) was converted to thallium(III) using saturated bromine water, then the solution was standardized complexometrically.
- **Thorium (IV) Nitrate (0.001 M) Solution:** A 0.01 M solution of thorium nitrate was prepared by dissolving the appropriate amount of thorium nitrate salt in double-distilled water and was subsequently standardized using a standard zinc(II) solution.

A working solution of thorium nitrate with a concentration of 0.001 M was prepared through proper dilution.

- **EDTA (0.001 M) Solution:** A standard 0.01 M solution of EDTA was created by dissolving 3.722 grams of disodium EDTA salt in 1.0 liter of double-distilled water and then standardized using complexometric analysis. A 0.001 M EDTA solution was prepared through appropriate dilution.
 - **N-n-Heptylaniline reagent Solution:** By the method of Z. G. Gardlund N-n-heptylaniline was synthesized and by using xylene as the diluent its solution (%v/v) was prepared.
 - **Indicator:** By accurate dilution working solutions were prepared. AR grade chemicals and very pure solvents were used.
3. **General Extraction Procedure:** An aliquot of solution containing 1 mg of thallium(III), add sufficient quantity of HCl to make the concentration of 1 M in a total volume of 15 mL. Into a 125 mL separating funnel transfer the solution and shake the solution for 1 minute with 10 mL of 0.10 M N-n-heptylaniline in xylene. Swirl the solution from the separating funnel and allowed to separate the two phases. The organic phase was backstripped twice with 40 mL of acetate buffer. The amount of thallium(III) was determined complexometrically, by adding excess of 0.001 M EDTA and back titrating against 0.001 M thorium nitrate using 0.1% xylenol orange indicator. Yellow to red violet is end point.

IV. RESULTS AND DISCUSSION

1. Influence of Acid Concentration on Extraction of Thallium (III)

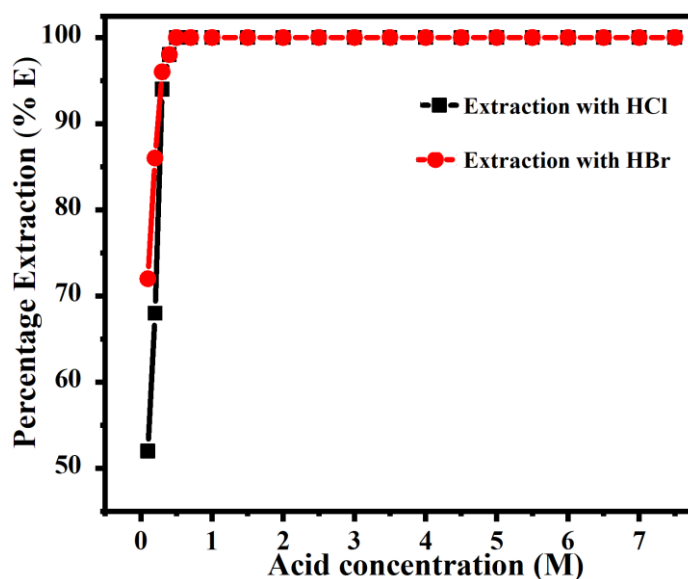


Figure 1: Effect of Acid Concentration

The extraction of 1 mg of thallium(III) was investigated using various acids, including hydrochloric, hydrobromic, nitric, sulphuric, and perchloric acid media, within the concentration range of 0.1 to 7.5 M. This extraction process utilized 0.10 M N-n-heptylaniline in xylene, maintaining an aqueous-to-organic volume ratio of 1.5:1. Thallium(III) extraction increased proportionally with the concentration of the acid, reaching full extraction efficiency in hydrochloric and hydrobromic acid media at concentrations between 0.5 and 7.5 M (refer to Figure 1). Throughout the study, a concentration of 1.0 M hydrochloric acid was consistently used due to its broader range of applications compared to hydrobromic acid. The other acids tested did not yield complete extraction.

- 2. Influence of Reagent Concentration on Extraction of Thallium (III):** The thallium(III) extraction was enhanced with an increase in the concentration of N-n-heptylaniline. Surprisingly, having an excess of extractant concentration did not negatively impact the extent of extraction (see Figure 2). It was determined that 10 mL of 0.10 M N-n-heptylaniline was adequate for the complete quantitative extraction of thallium(III) from a solution of 1.0 M hydrochloric acid. As a result, the recommended procedure involves using 0.10 M N-n-heptylaniline in xylene to ensure the comprehensive extraction of thallium(III).

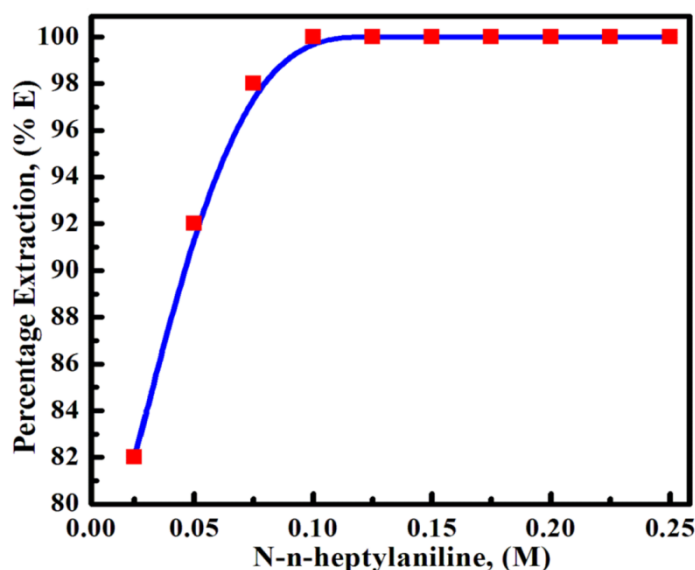


Figure 2: Effect of N-n-Heptylaniline Concentration

- 3. Effect of Shaking Time on Extraction of Thallium (III):** A study was conducted to investigate the impact of shaking time. A series of experiments were performed with varying durations of shaking time while maintaining a constant aqueous-to-organic ratio of 1.5:1, 0.10 M N-n-heptylaniline, and 1.0 M hydrochloric acid. The system was observed over a range of 10 seconds to 3 minutes to assess the effect of shaking time. It was determined that the extraction was quantitative within the timeframe of 15 seconds to 3 minutes (refer to Figure 3). As a result, the proposed method employs a 1-minute shaking time for achieving quantitative extraction.

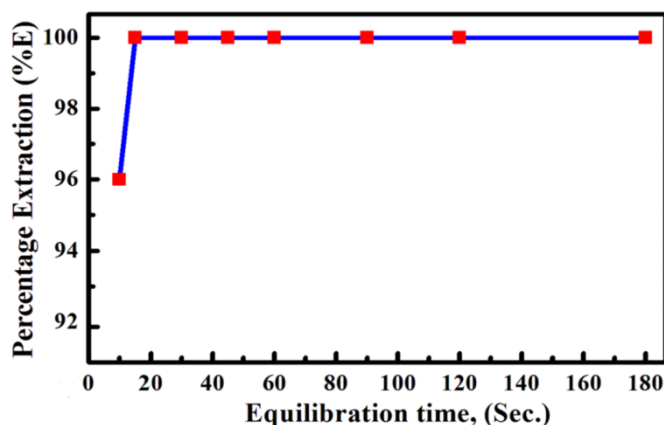


Figure 3: Influence of Shaking Time

- 4. Effect of various Diluents on Extraction of Thallium (III):** The selection of an appropriate solvent is essential for the solvent extraction method. At optimum condition the extraction of thallium(III) was studied with 0.10 M N-n-heptylaniline by changing solvents. Solvents having low dielectric constant with few exceptions such as carbon tetrachloride, amyl acetate, methyl isobutyl ketone and nitrobenzene, the extraction of thallium(III) was quantitative. It was incomplete with ethyl acetate and n-butanol. The results are tabulated in (Figure 4). The xylene was selected as the diluent as it gives clear-cut separation of the phases.

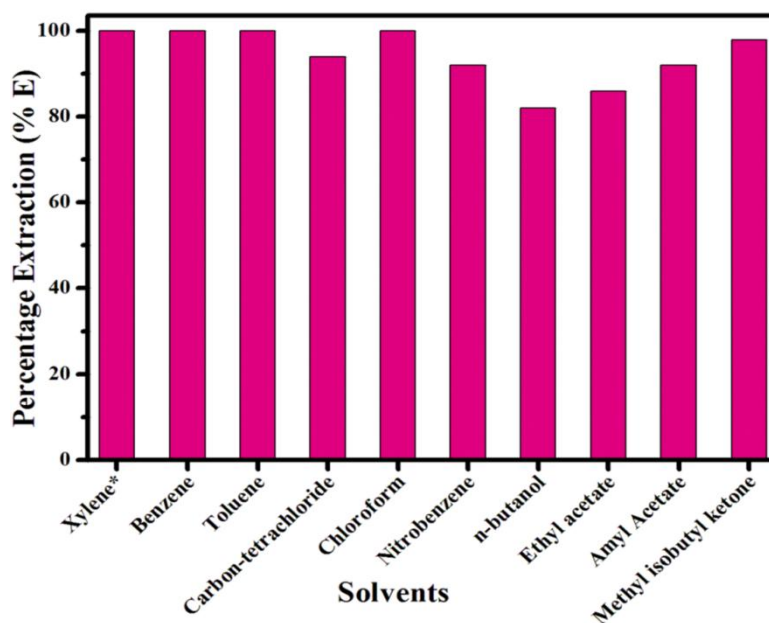


Figure 4: Influence of Solvents

- 5. Influence of Phase Ratio on Extraction of Thallium (III):** The investigation aimed to determine the permissible phase volume ratio for the effective extraction of thallium(III) using N-n-heptylaniline under optimal conditions, ranging from 1:1 to 20:1. The results of the study indicate that quantitative extraction occurs within phase ratios of up to 4:1.

However, beyond the 4:1 phase ratio, the extraction diminishes, possibly due to the reduced stability of the formed ion pair (refer to Figure 5).

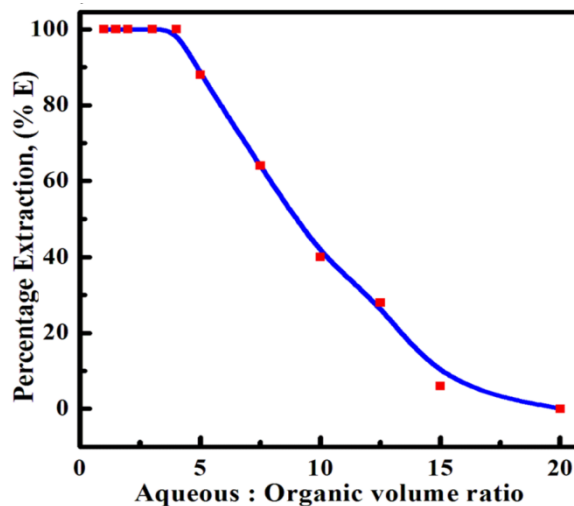


Figure 5: Influence of Volume Ratio

- Effect of Strippants:** Number of strippants were tried to strip thallium(III) from loaded N-n-heptylaniline. Thallium(III) was back stripped completely with acetate buffer having (pH 4.63) (2×40 mL) solution while in other strippants like sulphuric acid, acetic acid, nitric acid, perchloric acid and water back stripping was incomplete (Table 1).
- Loading Capacity:** Maximum capacity of the reagent to extract metal from aqueous to organic phase is studied. From the results it seems that the quantitative extraction of metal takes place upto 5 mg. At higher concentration of thallium(III), extraction decreased (Table 2). Thus, this study indicates that 5 mg of thallium(III) was a loading capacity of 10 mL 0.10 M N-n-heptylaniline in xylene.
- Influence of Temperature on Thallium (III) Extraction:** The experiment commenced with a solution of 0.10 M N-n-heptylaniline in xylene, and it was conducted in the presence of 1.0 M HCl at varying temperatures ranging from 298 to 323 K. The results revealed that the distribution ratio for the extraction of thallium(III) by N-n-heptylaniline in xylene increases as the temperature rises. The relationship between the distribution ratio (K_{ex}) and temperature is described by the Van't Hoff equation.

$$\frac{D(\log K_{ex})}{d(1/T)} = \frac{-(\Delta H)}{(2.303 R)} \quad (I)$$

Here note that, instead of T, K is taken for graph, where K = absolute temperature.

The graph of $\log K_{ex}$ vs $1000/K$ is a straight line having slope -4.10 (Figure 6) and the enthalpy $\Delta H = 78.31 \text{ KJ mol}^{-1}$ which states that the reaction is an endothermic process.

$$\Delta G = -2.303 RT \log K_{ex} \quad (II)$$

$$\Delta S = \Delta H - \Delta G/T \quad (III)$$

ΔG and ΔS values are calculated by using equations (II), (III) and results are tabulated in (Table 3). As the value of ΔG is negative the reaction is spontaneous.

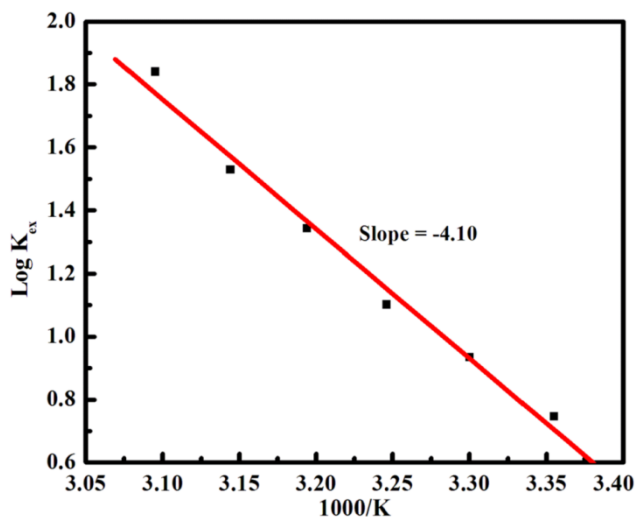


Figure 6: Effect of Temperature on Extraction

9. Stoichiometry of the Extracted Species: The extraction mechanism of thallium(III) was determined by analyzing the experimental data. Stoichiometry was determined using the traditional slope analysis method. Extracted species was determined by using graph $\text{Log } D_{[Tl(III)]}$ vs $\text{log } C_{[N-n\text{-heptylaniline}]}$ (Figure 7) 0.61 and 0.99 are the slopes of straight lines at 0.1 and 0.4 M HCl. Hence, it is evident that the species is 1:1.

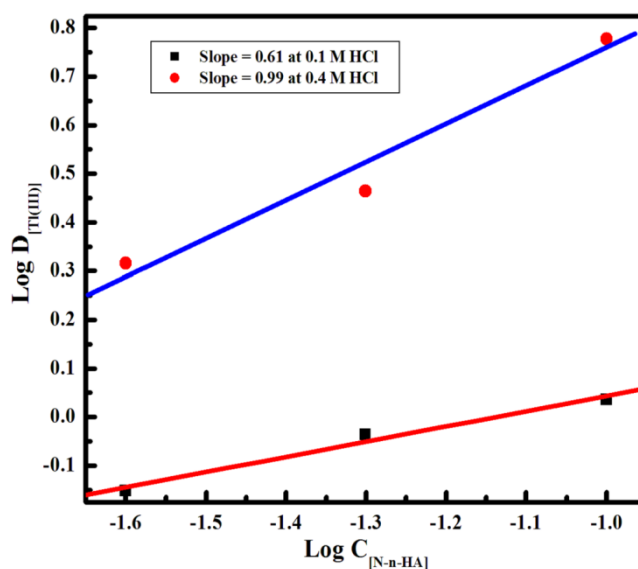
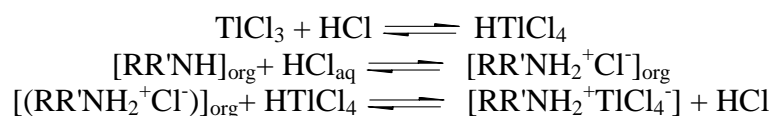


Figure 7: Log-Log graph of $\text{Log } D_{[Tl(III)]}$ Vs $\text{Log } C_{[N-n-HA]}$

The probable extraction mechanism may be as follows,



Here, R and R' are organic groups such as, -C₆H₅ and -C₇H₁₅.

10. Influence of Foreign Ions: Through the extraction process, the impact of many foreign ions that are frequently connected to thallium(III) was investigated. Table 4 provided the tolerance limits for the test ions. Upon determining that the interference was severe, the experiments were conducted again, this time utilizing progressively fewer quantities of potential foreign ions to ensure that the thallium(III) recovery error was less than $\pm 2\%$. The investigation demonstrates that the technique is unaffected by a significant amount of cations and anions. Mercury(II), bismuth(III), and zinc(II) are co-extracted.

V. APPLICATIONS

- 1. Thallium (III) Separation from Binary Mixtures:** The method was applied for the extraction and separation of thallium(III) from a number of synthetic binary mixtures. Metal under study was quantitatively extracted, separated from associated metal ion in binary mixture by proposed method. Associated metals were determined by separate methods (58, 59, 60). The results are given in (Table 5).
- 2. Analysis of Thallium (III) in Synthetic Ternary Mixtures:** The validity of the method was applicable for the analysis of synthetic mixtures of various compositions. From the results of triplicate analysis demonstrate that it is possible to separate and identify thallium(III) from the ternary mixtures (Table 6).
- 3. Alloy Analysis:** Synthetic mixtures of standard alloys were prepared. A known amount of alloy was dissolved in a dilute nitric acid (3.5 M) then the solution was boiled with 1:1 HNO₃ (5 mL) and filtered. Further filtrate is made 100 mL in volumetric flask. Then, thallium(III) was determined by general extraction method (Table 7).

VI. CONCLUSION

The influence of concentration of acid, N-n-heptylaniline concentration, solvents, contact time, phase ratio, metal loading capacity, temperature effect, stripping agent, foreign ions and synthetic mixtures have been analyzed. The thallium(III) was quantitatively extracted from HCl and HBr having concentrations 0.5 to 7.5 M using a xylene solution of 0.10 M N-n-heptylaniline. To backstrip thallium(III) from the loaded organic phase acetate buffer having pH 4.63 solution was used. Then it was standardized complexometrically. The recommended method is used for selective and rapid separation of thallium(III) from associated ions in their alloy samples, binary and ternary synthetic mixtures.

Table 1: Influence of Strippant on Extraction of Thallium (III)

HCl = 1.0 M, Tl(III) = 1.0 mg, N-n-heptylaniline = 0.10 M in xylene, Volume ratio : 1.5 : 1, Equilibration time = 1 min.,

Sr. No.	Stripping agent(M)	HNO ₃		H ₂ SO ₄		HClO ₄		NH ₃		CH ₃ COOH	
		% E ^a	D ^b	% E ^a	D ^b	% E ^a	D ^b	% E ^a	D ^b	% E ^a	D ^b
1	0.1	8.0	0.13	18.0	0.33	14.0	0.24	0.0	-	8.0	0.13
2	0.5	12.0	0.20	26.0	0.53	22.0	0.42	0.0	-	12.0	0.20
3	1.0	18.0	0.33	28.0	0.58	36.0	0.84	0.0	-	18.0	0.33
4	2.0	22.0	0.42	32.0	0.62	42.0	1.09	4.0	0.06	18.0	0.33
5	3.0	26.0	0.53	38.0	0.92	42.0	1.09	8.0	0.13	22.0	0.42
6	4.0	34.0	0.77	44.0	1.18	48.0	1.38	10.0	0.17	24.0	0.47
7	5.0	46.0	1.28	52.0	1.63	60.0	2.25	16.0	0.29	28.0	0.58
8	6.0	58.0	2.07	58.0	2.07	74.0	4.27	16.0	0.29	28.0	0.58
9	7.0	58.0	2.07	60.0	2.25	78.0	5.32	18.0	0.33	28.0	0.58
10	8.0	62.0	2.45	60.0	2.25	88.0	11.0	20.0	0.38	30.0	0.64
11	9.0	62.0	2.45	62.0	2.45	100.0	∞	0.0	-	30.0	0.64
12	10.0	62.0	2.45	64.0	2.67	100.0	∞	0.0	-	32.0	0.71

% E^a = Percentage extraction

Stripping agent

- (2×40 mL) Acetate buffer (pH 4.63)
- (H₂O) Water

D^b = Distribution ratio

Percentage Recovery (% R)

- 100.0
- 68.0

Table 2: Loading Study of N-n-Heptylaniline

HCl = 1.0 M, Tl(III) = 1.0 - 10.0 mg, N-n-heptylaniline = 0.10 M in xylene, Volume ratio : 1.5 : 1, Equilibration time = 1 min., Strippant = (2×40 mL)Acetate buffer (pH – 4.63)

Sr. No.	Metal,(mg)	% E ^a	D ^b
1	0.50	100.0	∞
2	1.0 to 5.0	100.0	∞
3	6.0	78.0	5.32
4	7.0	62.0	2.45
5	8.0	46.0	1.23
6	9.0	38.0	0.92
7	10.0	32.0	0.71

% E^a = Percentage extraction

D^b = Distribution ratio

Table 3: Effect of Temperature

HCl = 0.5 M, Tl(III) = 1.0 mg, N-n-heptylaniline = 0.10 M in xylene, Volume ratio : 1.5 : 1, Equilibration time = 1 min., Strippant = (2×40 mL)Acetate buffer (pH – 4.63)

Sr. No.	Temp. (K)	1000/K	E ^a	D ^b	Log D	Log K _{ex}	ΔG	ΔS	ΔH
1	298	3.355	78.72	5.54	0.7441	0.7463	-4258	14.55	78.31
2	303	3.300	85.10	8.56	0.9328	0.9350	-5424	18.16	
3	308	3.246	89.36	12.6	1.1002	1.1024	-6501	21.36	
4	313	3.194	93.61	21.9	1.3411	1.3433	-8050	25.97	
5	318	3.144	95.74	33.7	1.5277	1.5299	-9315	29.54	
6	323	3.095	97.87	68.9	1.8383	1.8405	-1138	35.48	

% E^a = Percentage extraction

D^b = Distribution ratio

Table 4: Influence of Foreign Ions

HCl = 1.0 M, Tl(III) = 1.0 - 10.0 mg, N-n-heptylaniline = 0.10 M in xylene, Volume ratio: 1.5 : 1, Equilibration time = 1 min., Strippant = (2×40 mL)Acetate buffer (pH – 4.63)

Sr. No.	Diverse ion	Tolerance limit (mg)
1	Al(III)	2.5
2	Mn(II)	5.0
3	Pb(II)	5.0
4	Cd(II)	5.0
5	Fe(III)	5.0
6	Ni(II)	5.0
7	Cr(III)	5.0
8	Cu(II)	5.0
9	Co(II)	5.0

10	Fe(II)	5.0
11	Ag(I)	5.0
12	Th(IV)	10.0
13	Ca(II)	30.0
14	Mg(II)	30.0
15	Ba(II)	30.0
16	Zn(II)	Co-extract
17	Hg(II)	Co-extract
18	Bi(III)	Co-extract
19	EDTA	50.0
20	Tartrate	50.0
21	Oxalate	100.0
22	Acetate	100.0
23	Nitrate	100.0
24	Nitrite	100.0
25	Phosphate	25.0

Table 5: Thallium (III) Separation from Synthetic Binary Mixtures

Sr. No.	Metal	Composition, mg	Average % Recovery
1	Tl(III)	1.0	99.9
	Al(III)	1.0	99.9
2	Tl(III)	1.0	99.9
	Cd(II)	1.0	99.8
3	Tl(III)	1.0	99.7
	Fe(III)	1.0	99.9
4	Tl(III)	1.0	99.8
	Pb(II)	1.0	99.7
5	Tl(III)	1.0	99.8
	Sb(III)	1.0	99.7
6	Tl(III)	1.0	99.9
	Th(IV)	1.0	99.8

Table 6: Analysis of Thallium (III) from Synthetic Ternary Mixtures

Sr. No.	Composition of the mixture (mg)	Thallium(III) found, (mg)	% recovery
1	Tl(III), 1; Ca(II), 1; Cd(II), 1	1.0	100.0
2	Tl(III), 1; Cu(II), 1; Fe(III), 1	1.0	100.0
3	Tl(III), 1; Ni(II), 1; Mg(II), 1	1.0	100.0
4	Tl(III), 1; Mn(II), 1; Fe(II), 1	1.0	100.0
5	Tl(III), 1; Ba(II), 1; Co(II), 1	1.0	100.0
6	Tl(III), 1; Cd(II), 1; Th(IV), 1	1.0	100.0

Table 7: Alloy Analysis

Sr. No.	Sample	Mixture, %	Amount of Tl(III) Taken, (mg)	Percentage Recovery, (% R)	Relative Standard Deviation (%)
1	Type metal alloy	Pb 80.0 Sn 17.0 Sb 3.0	1.0	99.4	0.6
2	Non-ferrous (Brass) alloy	Pb 2.0 Cu 65.0 Zn 30.0 Sn 1.0	1.0	99.6	0.4

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