Ion Exchange Extraction of Boron from Aqueous Fluids by Amberlite IRA 743 Resin

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The ion exchange characteristics of Amberlite IRA 743 resin for extracting boron from aqueous fluids have been investigated in detail. The results show that Amberlite IRA 743 resin, a boron-specific ion exchange resin, can quantitatively extract boron as the $B(OH)_4^-$ species from weakly basic solution. Some exchangeable anions such as Cl^- and SO_4^{2-} are present, resulting in an increase in pH value of the loaded solution within the column, and the boron in natural aqueous fluids with low pH is also extracted by Amberlite IRA 743 resin. However, the volume of loaded solution must be restricted. The maximum volume of loaded solution giving quantitative extraction of boron decreases for sample solutions of lower pH value. Warm HCl solution is more effective than room temperature HCl solution for eluting boron from Amberlite IRA 743 resin.

Keywords separation of boron, ion exchange, boron specific resin

Introduction

Before introduction of a sample into a mass spectrometer for boron isotopic analysis, it is usually necessary to separate boron from natural samples to avoid suppression of ionization of the boron species analyzed, to eliminate isobaric interference and to maintain a high vacuum in the mass spectrometer. Classically, boron extraction from aqueous samples was carried out by methyl borate distillation[1,2] or by ion exchange using anion, cation and boron-specific resin. Recently, the ion exchange technique using Amberlite IRA 743, a boron-specific resin, to separate boron from natural samples has been developed rapidly due to it's high boron exchange capacity. Kunin[3] first reported a characterization of Amberlite IRA 743 resin for removing boron from irrigation water. The column procedure for sample purification using Amberlite IRA 743 resin was first described by Kiss.[4] At present Amberlite IRA 743 resin is utilized widely for separation of boron from natural samples.[5-8] Aggarwal[5] emphasized that the pH value of boron-containing solution must be adjusted to at least 10, by addition of NH_4OH, for converting all boron to the $B(OH)_4^-$ species because only the $B(OH)_4^-$ species is absorbed onto the Amberlite IRA 743 resin. Different pH values of solutions, however, have been used. For example, Kiss[4] and Leeman[6] adjusted the pH values of solutions to 7.0 and 8.0, respectively. Tonarini[7] adjusted the pH of solution to 10—12. Davidson[8] suggested that the pH value of sample solution could be as low as 5.0, and recently Lemarchand[9] indicated that the pH value of the loaded solution could be as low as 5.5.

The main objective for the present study was to survey the influences of the pH value of loaded solution on absorption of boron by Amberlite IRA 743 resin. An improved method for eluting boron from Amberlite IRA 743 resin using 0.1 mol/L HCl at 75 ℃ is also reported in this study.

Experimental

Reagents

High-purity water having a boron blank of lower than 0.4 ng B/mL, produced by sub-boiling distillation and passage through boron-specific resin, was used. 2 mol/L HCl solution was prepared from concentrated HCl and high-purity 0.1 mol/L HCl was produced by the equilibrium method in a sealed vessel.

Amberlite IRA 743, a boron-specific ion exchange resin, was produced by Rohm and Hass Co. The resin contains *N*-methylglucamine groups fixed on a polystyrenic backbone. This tertiary amine is a weak base with $pK_A \approx 7$. Consequently, the resin behaves as an anion exchanger at pH < 7. Boron is strongly fixed onto the alcohol groups of the glucamine for pH values from neutral to alkaline, following the reaction:[9]

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$$H_3BO_3 + R-\underset{\underset{CH_3}{|}}{N}-C_6H_8(OH)_5 \rightleftharpoons R-\underset{\underset{CH_3}{|}}{N}-C_6H_8(OH)_3B\bar{O}_2(OH) + H^+ + H_2O \quad (1)$$

The boron capacity of this resin for a 0.1 mol/L boron solution is 11.76 mg B/g.[4]

Ion exchange procedure

The ground and sieved resin (*ca*. 80—100 mesh), after soaking in water, was loaded into a polyethylene column with a diameter of 0.4 cm. The length of the resin bed was adjusted to 5.5 cm and the resin was conditioned by addition of 10 mL of HCl (2.0 mol/L), 10 mL of high purity water, 10 mL of NH_4OH (2.0 mol/L) and 10 mL of high purity water successively. The sample solutions were loaded onto conditioned Amberlite IRA 743 resin at a flow rate of 0.5 mL/min. The column was then rinsed with 10 mL of high purity water, 10 mL of NH_4OH (2.0 mol/L) and 10 mL of high purity water successively to elute Cl^- and SO_4^{2-} off the resin. Finally, the boron held by the resin was eluted using approximately 10 mL of HCl (0.1 mol/L) at 75 ℃.

Analysis of boron

The concentration of boron in all solutions was examined using the Azomethine-H spectrophotometric method described by Kiss.[4] 1.00 mL of boron solution, 2.00 mL of buffer solution (250 g of NH_4AC, 15 g of EDTA, and 125 g of glacial HAC, diluted to 400 mL), and 2.00 mL of Azomethine-H solution (0.45 g of Azomethine-H and 1 g of ascorbic acid in 100 mL of water) were sequentially added into a quartz chamber. After mixing well, the solution was allowed to stand for 30 min and then the absorbance of the boron-Azomethine-H complex at 410 nm was measured using Turner 690 (made in USA) and 721 model (made in Shanghai Third Analytical Instrument Factory, China) spectrophotometers. The precision of this method was ±2%.

Results and discussion

Effect of pH *of the loaded solution on boron uptake and retention*

Boron occurs as both $B(OH)_3$ and $B(OH)_4^-$ species in aqueous fluids. Most studies have shown that the distribution of $B(OH)_3$ and $B(OH)_4^-$ in solution is extremely dependent on the pH of the solution.[10-12] The $B(OH)_4^-$ species dominates when the pH value of the solution is higher than 10. Lemarchand[9] evaluated the influence of the pH value of the solution on boron absorption by the resin in batch exchange. The result indicated that the partition coefficient, representing the affinity of the resin for boron, increases with the increase of pH value of the sample solution in a pH range of 1.5 to 7.0. This result suggests that the absorption and retention of boron by Amberlite IRA 743 resin during column exchange should decrease at lower pH values.

The influence of the pH value of the loaded solution on boron absorption and retention by Amberlite IRA 743 resin in column exchange was tested here for pH values in the range of 1.00 to 14.0. The pH values of the tested solutions were adjusted by adding HCl or NaOH solution and measured using pH meter with a precision of 0.01 unit of pH. The results, as shown in Table 1, show that the absorption and retention of boron from 10 mL of loaded solution does not change with pH value of the solution in the range of 2.16 to 13.0, while the retention of boron distinctly decreases for solutions with pH value 1.00 and 14.0.

Effect of the volume of loaded solution on boron uptake and retention

The influence of the volume of loaded solution on the retention of boron by Amberlite IRA 743 resin was studied for solutions with initial pH values in the range of 1.00 to 13.0. The results listed in Table 2 show that the maximum volume of loaded solution giving complete retention of boron decreases for solutions with lower pH value. The retention of boron is significantly lower when the volume of loaded solution is larger than the maximum volume. For example, the retention of boron for 1.00 mL of loaded solution with initial pH value of 1.00 is 98.0%, but when the volumes of solution are 4.00 and 8.00 mL, the retentions of boron decrease to 46.6% and 16.4%, respectively. The retention of boron is also nonquantitative for 30 mL of loaded solution when the acidity of the solution is pH 2.00. As seen in Table 2, the maximum volume of solution giving quantitative retention of boron increases rapidly with increase of the initial pH value of loaded

Table 1 Recovery of boron from 10 mL of loaded solution at different pH values

	pH value										
	1.00	2.16	3.13	4.13	5.09	6.76	8.97	10.0	12.0	13.0	14.0
Added boron (μg B)	20.0	20.0	20.0	20.0	20.1	19.9	19.9	19.8	20.0	20.1	20.1
Recovered boron (μg B)	3.01	20.3	19.5	19.1	19.5	20.0	19.4	19.4	19.3	20.0	18.8
Recovery (%)	15.0	102	97.5	95.5	97.5	100	97.5	98.0	96.5	99.5	93.5

Table 2 Effect of volume of solution on the recovery of boron at various pH value

	pH values											
	1.00	1.00	1.00	2.01	2.01	2.01	3.00	3.00	3.00	4.00	4.00	4.00
Solution volume (mL)	1.00	4.00	8.00	10.0	20.0	30.0	40.0	210	500	210	500	750
Added B (μg)	19.8	19.9	19.9	19.6	19.7	19.7	19.4	20.0	19.8	20.0	19.9	20.0
Recovered B (μg)	19.4	9.28	3.26	19.4	19.5	15.0	4.67	19.9	13.2	19.7	20.4	19.7
Recovery (%)	98.0	46.6	16.4	99.0	99.0	76.1	24.0	99.5	66.7	98.5	102	98.5

	pH values										
	4.00	5.00	5.00	6.00	6.00	8.00	10.0	10.0	11.0	11.0	13.0
Solution volume (mL)	1000	500	1000	500	1000	1000	1000	1500	1000	2000	1000
Added B (μg)	20.0	19.9	19.5	20.0	19.8	19.8	19.2	19.8	19.6	20.0	19.4
Recovered B (μg)	19.5	19.9	19.5	20.0	19.8	19.8	19.2	19.6	19.6	20.0	19.4
Recovery (%)	97.5	100	97.7	100	99.0	98.0	96.5	98.9	98.0	99.5	97.5

solution. These maximum volumes at various pH values of loaded solution are plotted in Fig. 1. Fig. 1 indicates that boron can be recovered completely from 1000 mL of solution when the pH value of the loaded solution is 4 or higher.

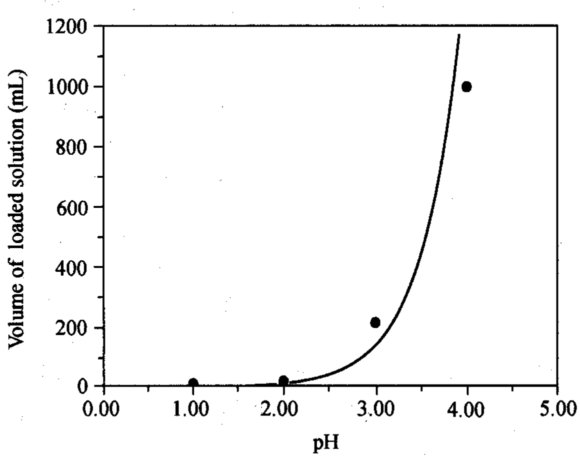


Fig. 1 Maximum volume of loaded solution allowing quantitative absorption and retention of boron versus pH (the column has a diameter of 0.4 cm and a resin bed length of 5.5 cm).

Effect of salinity of loaded solution on the uptake and retention of boron

Lemarchand[9] indicated that recovery of boron by Amberlite IRA 743 resin was better from lower ionic strength solution than higher ionic strength solution (both at pH = 5.5). The effect of NaCl content in loaded solution (at pH = 2) on the recovery of boron using Amberlite IRA 743 resin was tested here. The results are shown in Table 3 which are different from those of Lemarchand. The present results suggest that at a pH value of 2.00 the presence of NaCl in the loaded solution is favorable for absorption and retention of boron by Amberlite IRA 743 resin. For complete retention of boron by the resin, the maximum volume of loaded solution (at pH = 2.00) is 30 mL in the absence of NaCl and 40 mL in the presence of 1.0 mol/L NaCl. The maximum allowable volume of loaded solution is larger for solutions with higher NaCl concentration. The reason for this contrast will be discussed in the next section.

Shift in the pH *of effluent from Amberlite* IRA 743 *resin columns*

The results listed in Table 2 apparently indicate that Amberlite IRA 743 resin can absorb boron from aqueous fluids at any pH. Actually, the resin only extracts the $B(OH)_4^-$ species from neutral or alkaline solution. The resolution of this apparent contradiction lies in the shift in the pH value of effluent often occurring when a boron-containing solution is passed through the Amberlite IRA 743 resin. This effect was observed in the following experiment. 60 mL of solution with the boron concentration of 0.82 μg B/mL and an initial pH value of 2.00 was loaded onto an Amberlite IRA 743 resin column and the effluent was collected in 10 mL portions. The pH value and boron concentration of each effluent portion were determined. The results are shown in Table 4. The pH values in the

Table 3 Effect of salinity of loaded solution on the recovery of boron at pH = 2.00

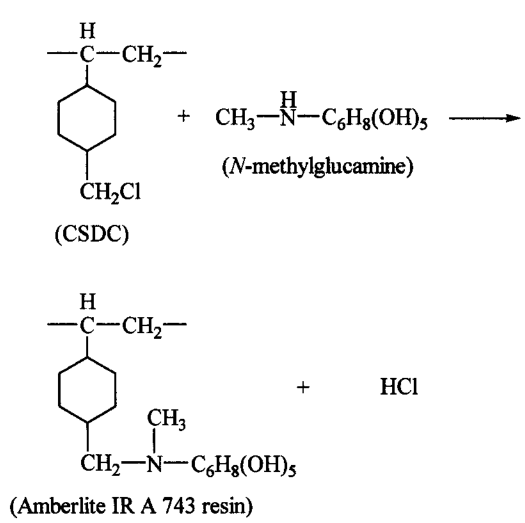
	Concentration of NaCl in loaded solution (mol/L)				
	0	1.0	1.0	3.6	3.6
Volume of loaded solution (mL)	40	40	60	40	100
Added boron (μg B)	20.1	19.7	19.9	20.1	19.8
Recovered boron (μg)	13.6	20.1	14.8	20.3	19.8
Recovery (%)	67.7	102	74.4	101	100

Table 4 Changes in pH and boron concentration in effluent from the column (the initial pH value and boron concentration of loaded solutions are 2.00 and 0.82 μg B/mL)

	Volume of effluent (mL)					
	10.3	10.7	9.6	10.4	9.3	8.8
pH value of effluent	9.85	9.83	9.92	6.06	2.41	2.08
Concentration of boron in effluent (μg B/mL)	0	0	0	0.19	1.63	1.18

first three effluent portions were 9.85, 9.83 and 9.92, respectively. No boron was detected in these solutions. The pH value of the fourth portion of effluent was 6.06 and the measured concentration of boron in this solution was 0.19 μg B/mL. The pH values of effluent in the fifth and the sixth portions decreased to 2.41 and 2.08 and detected concentrations of boron in these solutions were 1.63 μg B/mL and 1.18 μg B/mL, respectively, which are higher than that of the loaded solution. These results make clear that the affinity of the resin for boron decreases with lower pH values of the solution in the column. The $B(OH)_4^-$ species, which can be absorbed by Amberlite IRA 743 resin, is the main boron species when the pH value of the loaded solution in the column is high. We emphasize that the pH of the solution in the resin column is not always the same as the initial pH value in the loaded solution. The affinity of the resin for boron is dependent on the pH value of the solution in the resin column, not the loaded solution.

Lemarchand[9] indicated that the tertiary amine fixed on the polystyenic backbone of the resin has the property to exchange anions with solution of pH$\leqslant$7. According to Eq. (1), however, the Cl^- or SO_4^{2-} ions can not be fixed onto the alcohol groups of the glucamine. Therefore the high pH values of the first three portions of effluent probably were not caused by the release of OH^- ion in the column when anions, such as Cl^- and SO_4^{2-}, are absorbed by Amberlite IRA 743 resin. Kunin and Preuss[3] prepared Amberlite IRA 743 by aminating a chloromethylated styrene-divinylbezene copolymer (CSDC) with *N*-methylglucamine, following the reaction:



Amberlite IRA 743, probably, contains small amount of CSDC, which has the property to exchange anions. However, the Cl capacity of CSDC can not be measured in this case because we do not know the contents of CSDC in the Amberlite IRA 743 resin. So we just test how Cl^- is exchanged by Amberlite IRA 743, actually by CSDC. The capacity of the resin for extracting Cl^- from aqueous fluids when conditioned by HCl alone and by HCl and NH_4OH was measured using NaCl solutions. The results, shown in Table 5, indicate that the additional uptake of Cl^- by the resin is very small when the resin has been conditioned by HCl alone. Meanwhile, the Cl^- uptake of the resin conditioned by HCl and NH_4OH is larger by a factor of 100. The Cl^- uptake of the resin also increased with increase in the concentration of NaCl in the loaded solution due to the presence of OH group in CSDC. The release of OH caused by exchange of Cl led to the increase in the pH value of solution in the column. The increase in pH results in the increase of partition coefficient of Amblite IRA 743 resin. In the study reported by Lemarchand,[9] however, there is no OH group present in CSDC. The presence of NaCl in the loaded solution does not result in the increase in pH. However, the amount of B fixed by Amblite IRA 743 resin is identical at pH = 5.5, $c(NaCl) = 0$ mol/L and pH = 8.6, $c(NaCl) = 0.6$ mol/L, which approves the influence of pH value of loaded solution on the partition coefficient of Amblite IRA 743 resin.

The pH value of the column effluent should no longer increase when the Cl^- capacity of the resin is reached. At this time the pH of the solution passing through the column should gradually return to the initial pH value of the loaded solution. Then the boron already absorbed by the resin may be eluted by the loaded solution if the initial pH value is low enough. In order to confirm this explanation, several experiments were carried out. The pH values of effluents were measured using pH meter when solutions of H_3BO_3, $Na_2B_4O_7$ and NaCl were loaded onto Amberlite IRA 743 resin columns. The shifts in pH values of effluents are plotted in Fig. 2. The graph indicates that the pH values of effluents essentially remain constant when loading H_3BO_3 and $Na_2B_4O_7$ solutions. In contrast, the pH value of the first 10 mL of effluent increased to 11.90 from 5.66 when loading 0.1 mol/L NaCl solution, and decreased back to pH = 7.00 in a total 60 mL of effluent. The increase in pH value is attributed to the absorption of Cl^- ion by CSDC and the release of OH^-.

Table 5 Capacity of Amberlite IRA 743 resin containing CSDC for extracting Cl^- from aqueous fluids

Conditioning solutions	Concentration of NaCl (mol)	Weight of dry resin (80—160 mesh) (g)	Absorbed Cl^- (mol)	Cl^- uptake (mol/g dry resin)
2 mol/L HCl alone	0.5	0.4776	2.70×10^{-6}	5.65×10^{-6}
	1.0	0.4812	2.70×10^{-6}	5.61×10^{-6}
	3.0	0.4905	7.00×10^{-6}	1.43×10^{-5}
2 mol/L HCl and 3 mol/L NH_4OH	0.5	0.4502	1.05×10^{-4}	2.32×10^{-4}
	1.0	0.4582	2.05×10^{-4}	4.47×10^{-4}
	2.0	0.4760	2.31×10^{-4}	4.85×10^{-4}
	3.0	0.4989	2.60×10^{-4}	5.21×10^{-4}

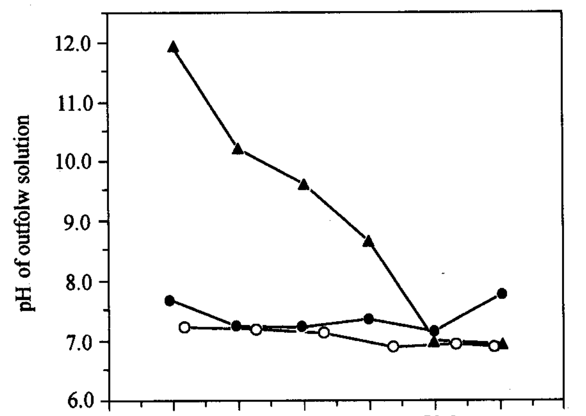


Fig. 2 Shift in pH of effluent when solutions of H_3BO_3, $Na_2B_4O_7$ and NaCl are loaded onto Amberlite IRA 743 resin columns. ●—83.3 μg B/mL of H_3BO_3 solution (pH = 6.95); ○—83.3 μg B/mL of $Na_2B_4O_7$ solution (pH = 7.25); ▲—0.1 mol/L NaCl solution (pH = 5.66)

Condition of Amberlite IRA 743

The above results suggest that it is necessary to condition Amberlite IRA 743 resin using NH_4OH if the sample solution has a low pH and lacks exchangeable anions other than OH^-. The following tests were carried out to investigate this. Test 1: 65.01 mL of borax solution with pH = 2.10 and 0.767 μg B/mL was passed through a column filled with Amberlite IRA 743 resin conditioned by HCl alone. Test 2: 69.06 mL of borax solution with pH = 2.10 and 0.781 μg B/mL was passed through a column filled with resin conditioned by HCl and NH_4OH. The pH value and boron concentration of the effluents were measured. The results are given in Table 6 and plotted in Fig. 3. The experimental results show that the pH value of the effluent at the begin in test 1 is not much higher than the initial pH value of the loaded solution. However, in test 2 the pH value of the effluent at the begin is much higher than the initial pH value of the loaded solution. In these tests, the boron concentration of the effluent is lower when the pH value of the effluent is higher. These results suggest that the initial increase in pH value of effluent can be attributed to the release of OH^- by the CSDC due to the absorption of Cl^- ion. It is very interesting that in test 2 the pH of effluent first increases from 2.10 to 8.89 and then decreases to 2.11, the approximate pH of the loaded solution. Meanwhile, the boron concentration of the effluent is zero at first, increases to 1.25 μg B/mL, which is higher than the boron concentration of the loaded solution, then decreases to 0.781 μg B/mL, close to the concentration in the loaded solution. The result indicates that the boron initially absorbed by the resin can be later eluted during continued loading of a solution with low pH value. Therefore, the recoveries of boron for the two tests are just the same.

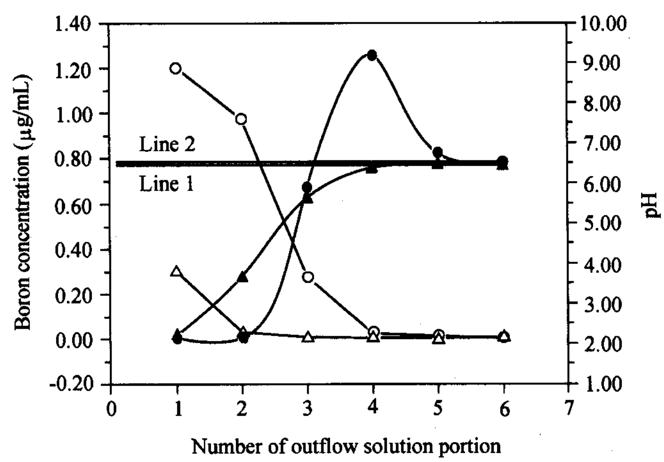


Fig. 3 Shifts in pH and boron concentration of effluent using Amberlite IRA 743 resin with and without conditioning by NH_4OH. Test 1. Resin is not conditioned with NH_4OH. ▲—The boron concentration of effluent. △—The pH value of effluent. The boron concentration of loaded solution is 0.767 μg B/mL (line 1). The recovery of boron using an elution solution of 0.1 mol/L HCl is 23.2%. Test 2. Resin is conditioned with NH_4OH. ●—The boron concentration of effluent. ○—The pH value of effluent. The boron concentration of loaded solution is 0.781 μg B/mL (line 2). The recovery of boron using an elution solution of 0.1 mol/L HCl is 24.0%.

The results listed in Table 5 indicate that Amberlite IRA 743 resin that has been conditioned with base can absorb Cl^- from NaCl bearing solution. The rate of decrease in pH of the effluent after its initial rise is reduced by thep-

Table 6 Changes in pH and boron concentration of effluent using the resin with or without conditioning by NH_4OH

No.	Effluent			Elution solution of 0.1 mol/L HCl		
	Volume (mL)	pH	Boron concentration (μg/mL)	Volume (mL)	Recovered boron (μg)	Recovery (%)
Test 1[a]						
1	10.11	3.79	0.011	22.58	12.1	23.1
2	10.45	2.27	0.275			
3	10.62	2.14	0.624			
4	10.18	2.12	0.755			
5	11.71	2.12	0.771			
6	10.66	2.13	0.767			
Test 2[b]						
1	11.03	8.89	0	23.72	12.9	23.9
2	11.41	7.58	0			
3	11.30	3.65	0.671			
4	10.58	2.23	1.254			
5	11.42	2.17	0.819			
6	12.40	2.11	0.781			

[a] The resin is not conditioned with NH_4OH. The volume, pH and boron concentration of loaded solutions are 65.01 mL, 2.10 and 0.767 μg B/mL, respectively. The total loaded boron is 52.3 μg. [b] The resin is conditioned with NH_4OH. The volume, pH and boron concentration of loaded solution are 69.06 mL, 2.10 and 0.781 μg B/mL, respectively. The total loaded boron is 53.9 μg.

resence of NaCl in the loaded solution due to a significant exchange of Cl^- for OH^- on the CSDC. The experimental results shown in Fig. 4 suggest that at low pH, the maximum volume of loaded solution allowing quantitative absorption and retention of boron should be larger for solutions with higher concentrationsof NaCl, as was demonstrated earlier by the data in Table 3.

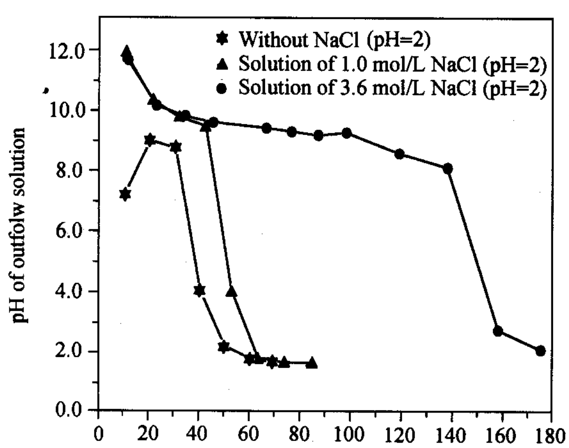


Fig. 4 Effect of NaCl content of loaded solution with pH 2 on the pH of effluent.

The pH values of seawater from 4°18′ N 161°08′ E, with a boron concentration of 4.61 μg/g and a pH of 8.28, was adjusted in a range from 2.02 to 6.94 by adding HCl solution and loaded onto Amberlite IRA 743 columns. The recoveries of boron from seawater with different pH values are shown in Table 7. The results suggest that the pH values of the sample does not influence the boron recovery when the volumes of seawater are about 10 mL. This means that the pH value of a sample is not a limiting parameter when the volume of sample solution is small and salt content is high enough.

Elution of boron

The boron absorbed by Amberlite IRA 743 resin can be eluted with HCl. In general, 2.0 mol/L HCl has been used.[4,6,7] Lemarchand[9] tested different molarities of HCl solutions and showed that the thinnest elution curves were observed for 0.1 mol/mL HCl. At higher molarities, the volume of acid necessary for a complete B recovery increases. Xiao[13] discovered that heated 0.1 mol/L HCl was a more effective eluent than that at room temperature. The elution effectiveness of 0.1 mol/L HCl at various temperatures was tested here and is shown in Table 8 and Fig. 5. In the temperature range examined, the data indicate that the higher the temperature of 0.1 mol/L HCl for the same volume of eluent, the better the recovery of boron from the resin. Complete recovery of boron was obtained when 7.9 mL of 0.1 mol/L HCl at 75 ℃ was used. In contrast, the recovery of boron was less than 70% when 7.8 mL of 0.1

Table 7 Recovery of boron from seawater at different pH values

No	Taken		pH	Discovered boron (μg)	Measured boron concentration (μg/g)	Recovery of boron (%)
	Seawater (g)	Boron (μg)				
1	10.0128	46.2	2.02	45.6	4.55	98.7
2	9.9975	46.1	2.94	45.4	4.54	98.5
3	10.0002	46.1	3.81	46.4	4.64	100.6
4	10.0182	46.2	5.02	46.6	4.65	100.9
5	10.0071	46.1	6.18	46.2	4.62	100.2
6	10.0309	46.2	6.94	46.4	4.62	100.4
7	10.0036	46.1	8.28	46.2	4.62	100.2

Table 8 Effect of temperature of 0.1 mol/L HCl elution solution on the recovery of boron

	Temperature of elution solution														
	25 ℃				55 ℃						75 ℃				
Volume of elution solution (mL)	5.5	7.8	11.3	15.1	3.1	5.4	7.3	9.2	11.6	14.1	3.3	5.4	7.9	9.8	11.9
Recovery of boron (%)	0	66.7	79.4	93.5	8.4	40.4	72.8	86.2	96.2	95.2	4.2	79.4	98.3	99.1	98.9

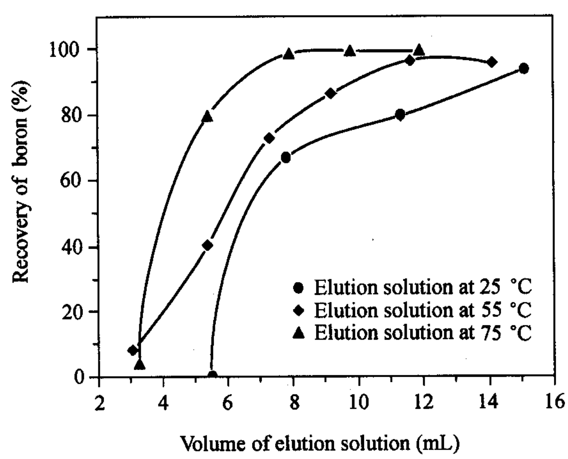


Fig. 5 Boron elution curves using 0.1 mol/L HCl eluent at different temperatures. Ion exchange extraction of boron from aqueous fluids by Amberlite IRA 743 resin

mol/L HCl at 25 ℃ was used. Fracturing of the resin beads and decrease in capacity of absorbed boron were not observed in the repeated use of Amberlite IRA 743 resin eluted with warm 0.1 mol/L HCl.

References

1 Kanzaki, T.; Yoshida, M.; Nomura, M. *Geochim. Cosmochim. Acta* **1979**, *43*, 1859.

2 Nomura, M.; Kanzaki, T.; Ozawa, T.; Okamoto, M.; Kakihana, H. *Geochim. Cosmochim. Acta* **1982**, *46*, 2403.

3 Kunin, R.; Preuss, A. F. *I & EC Product Research and Development* **1964**, *3*, 304.

4 Kiss, E. *Anal. Chim. Acta* **1988**, *211*, 243.

5 Aggarwal, J. K.; Palmer, M. R. *Analyst* **1995**, *120*, 1301.

6 Leeman, W. P.; Vocke, R. D.; Beary, E. S.; Paulsen, P. J. *Geochim. Cosmochim. Acta* **1991**, *55*, 3901.

7 Tonarini, S.; Pennisi, M.; Leeman, W. P. *Chem. Geol.* **1997**, *142*, 129.

8 Davidson, G. R.; Bassett, R. L. *Environ. Sci. Technol.* **1993**, *27*, 172.

9 Lemarchand, D.; Gaillardet, J.; Göpel, C.; Manhès, G. *Chem. Geol.* **2002**, *182*, 323.

10 Spivack, A. J.; Edmond, J. M. *Geochim. Cosmochim. Acta* **1987**, *51*, 1033.

11 Palmer, M. R.; Spivack, A. J.; Edmond, J. M. *Geochim. Cosmochim. Acta* **1987**, *51*, 2319.

12 Xiao, Y. K.; Wang, L. *Chem. Geol.* **2001**, *171*, 253.

13 Xiao, Y. *M. S. Thesis*, University of Memphis, Memphis, **1996**.

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