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K. N. Kmak, J. D. Despotopulos, N. D. Scielzo

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Title page

Names of the authors: Kelly N. Kmak[1], John D. Despotopulos[1], Nicholas D. Scielzo[1]

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Affiliation(s) and address(es) of the author(s): Nuclear and Chemical Sciences Division, Lawrence Livermore National Laboratory, Livermore, CA, USA

E-mail address of the corresponding author: kmak1@llnl.gov

Uptake Behavior of ^{73}As, ^{75}Se, ^{197m}Hg, ^{212}Pb and ^{210}Po on Eichrom Pre-Filter Resin from HCl and HNO_3

Kelly N. Kmak[1], John D. Despotopulos[1], Nicholas D. Scielzo[1]

[1] *Nuclear and Chemical Sciences Division, Lawrence Livermore National Laboratory, Livermore, CA, USA*

Abstract

The extraction of ^{73}As, ^{75}Se, ^{197m}Hg, ^{212}Pb and ^{210}Po on Eichrom pre-filter resin was studied in HCl and HNO_3 with batch uptake, kinetic and column experiments. There was significant extraction of mercury in HNO_3 and HCl, and polonium and selenium in HCl. The kinetics are sufficient to allow for retention on pre-filter columns, and separations of ^{73}As from ^{75}Se and ^{197m}Hg, and ^{212}Pb from ^{210}Po are demonstrated. This retention is important for the development of chemical separations as pre-filter resin is commonly used alongside extraction chromatography resins but its potential for uptake of metal ions is not well characterized.

Keywords

Pre-filter resin, mercury, selenium, polonium, extraction chromatography

Introduction

Eichrom Technologies' pre-filter resin is commonly used in radiochemical procedures for numerous separation applications including environmental monitoring [1] [2], nuclear medicine [3] [4] and geochemistry [5] [6]. This resin is often included in chemical procedures to remove undesirable organic matter, either arising from the samples themselves or from previous separation steps. It is particularly useful in conjunction with Eichrom extraction chromatography resin, such as TRU, where organic material leaches

off the resin during column elution. However, there are minimal details available on the exact composition of pre-filter resin. Eichrom does not provide any technical documentation about pre-filter resin, only describing it as an "uncoated, inert polymeric support" [7]. Triskem International, the European sister corporation of Eichrom, also distributes pre-filter[1] resin [8] and includes more information on the product sheet, describing the resin as "hydrophilic, macroporous, acrylic ester polymeric resin with a pore size of approx. 25 nm and a narrow pore size and pore volume distribution" and specifying the surface area (~ 500 m^2/g) [9].

Despite the widespread use of this resin [1-6] [10] [11], there is a lack of data available in the literature about the potential for the uptake of elements on pre-filter resin itself. However, it is known that pre-filter resin is not entirely inert for some separations. For example, astatine can be retained on pre-filter resin, which has been used for effective separation of astatine from bismuth [12]. Furthermore, other soft cations, like selenium [13] and mercury [14], are known to retain on acrylic plastics and, therefore, may retain on pre-filter resin.

There is considerable interest in utilizing Eichrom and Triskem extraction chromatography resin for separations involving mercury and selenium [4] [13] [15] and Triskem is developing a dedicated resin for selenium separations [16]. Separations of interest for mercury are generally for radiopharmaceutical and environmental applications, as mercury is a common environmental pollutant and a potential isotope for nuclear imaging (^{197m}Hg [17] [18]). Selenium separations are also of interest for similar applications as ^{72}Se is the parent of ^{72}As (a potential isotope for medical imaging) [19] and ^{79}Se is a long-lived fission product with environmental implications. Selenium and arsenic isotopes are also early targets for isotope harvesting applications at the Facility for Rare Ion Beams (FRIB) for use in a range of experiments including biochemistry, medical, astrophysics, and nuclear-security experiments [20]. Due to the prevalence of employing pre-filter resin alongside Eichrom and Triskem extraction chromatography resins, it is crucial to understand how

[1] Triskem International documentation does not include a hyphen in the name of this resin ("prefilter resin"), while Eichrom hyphenates ("pre-filter resin"). In the literature, there is no consistency in the inclusion of a hyphen even when referring to the product obtained from Eichrom. In this work, the hyphenated form will be used as the default.

these elements may interact with pre-filter resin, especially as there is known uptake of selenium and mercury on similar plastic materials.

Studies were undertaken to determine if selenium and mercury were retained by prefilter resin, and under what conditions, as this could impact the development of separation methods for these two elements. In addition to selenium and mercury, lead, arsenic and polonium were also studied. Polonium was selected as it is frequently an element of interest in environmental separations with Eichrom resins [21] [22] [23] and, as a homolog of selenium, is likely to share many chemical characteristics. Arsenic was selected as arsenic/selenium separations are relevant for radiopharmaceutical production, as mentioned previously [19] [24], and understanding the behavior of both of these elements is critical for high-purity, high-yield separations. Finally, lead was chosen as it is often an important element for geochemical procedures with Eichrom resins [25], Eichrom has a dedicated resin for lead separations (Pb resin), and it is known to retain on plastics in some circumstances [26]. The uptake behavior of these elements was studied with batch, kinetics, and column studies with pre-filter resin in HCl and HNO_3 solutions. Experiments were conducted in acidic solutions with pH <2 as polonium and mercury have a strong tendency to hydrolyze at pH values greater than 2 [27] [28].

Experimental

Pre-filter resin (Eichrom Technologies, 150-200 μm) was used for all batch and kinetics studies; column studies were performed with pre-packed, 2 mL cartridges. ULTREX II ultra-pure acids (J.T. Baker), diluted with Aristar ultra-pure water (VWR International) as necessary, were used for all solutions. The concentrated solution of HCl was 11.3 M and the concentrated solution of HNO_3 was 15.2 M. A solution of 1% (w/w) NaCl (ACS reagent, ≥99.0%, Sigma) was prepared with Aristar ultra-pure water.

The isotopes used in this work are listed in Table 1. Mercury-197m was obtained via proton irradiation of natural gold foils. The irradiation conditions and subsequent separation of ^{197m,g}Hg from ^{nat}Au have been described previously [4] [29]. Isotopes generators were used to produce ^{210}Po (Ref. [30]) and ^{212}Pb (Ref. [31]). Arsenic and

selenium were obtained through the National Isotope Development Center (NIDC). Selenium-75 was produced at the University of Missouri Research Reactor (MURR) from neutron irradiation of ^{nat}Se. It was received in ~6 M HNO_3 and diluted to 1 M HNO_3; aliquots of this stock solution were further diluted as needed for use in experiments. Due to these dilutions, the final concentration of ^{nat}Se in this work was 0.11 ppb (1.5×10^{-9} M). Carrier-free ^{73}As was produced via proton irradiation of ^{nat}Ge at Los Alamos National Laboratory; it was received as a solution in 0.1 M HCl and used directly.

Table 1 Relevant nuclear data for the isotopes used on this work including half-lives, decay modes, photopeaks, and intensities [32].

Isotope	Decay Mode	Half-Life	Photopeak (keV)	Intensity (%)
^{73}As	ε	80.30 d	53.437	10.6
^{75}Se	ε	119.78 d	136.000	58.5
^{197m}Hg	IT/ε	23.8 h	133.98	33.5
^{212}Pb	β^-	10.62 h	238.632	43.6
^{210}Po	α	138.38 d	n/a	n/a

Activity measurements were performed by both gamma spectrometry and liquid scintillation counting (LSC). As ^{210}Po does not have a suitable gamma-ray emission, activity measurements for this isotope were performed with a Quantulus Liquid Scintillation Counter; the built-in software, QuantaSmart (Revvity), was used to analyze spectra. All LSC samples were prepared in glass 20 mL scintillation vials with Ultima Gold AB cocktail (Revvity) and measurements were made relative to a ^{210}Po counting standard. As no other isotopes were present in samples with ^{210}Po, no α/β discrimination techniques were required.

For all other isotopes, activity measurements were performed with an HPGe gamma-ray detector with Ortec NIM electronics and ASPEC multi-channel analyzer. Spectra were analyzed with Maestro software (Ortec). All samples were counted in the same geometry and measurements were conducted immediately after completion of the batch, kinetics, and column studies. Decay corrections to account for decay during the experiments were necessary for ^{197m}Hg and ^{212}Pb due to their short half-lives (Table 1). For all other isotopes,

the experimental time and count times were negligible compared to the half-life. For each isotope, the highest intensity gamma-ray line was used to determine the activity.

Batch Uptake Studies

Stock solutions for the tracer isotopes were prepared as described in Table 2. Most of the solutions were prepared in 2 M acid (HCl or HNO_3). Solutions for selenium were prepared differently due to the need for redox control in HCl as well as the high volatility, which makes evaporations challenging. As Se^{4+} was desired for studies in HCl, these solutions were prepared immediately before use in experiments (as described in Ref. [13]) in 11 M HCl. For studies in HNO_3, selenium solutions were obtained by diluting the stock solution to the desired activity level, removing the need for evaporations. Polonium solutions were prepared identically to the selenium solutions for ease of comparison between these elements as they are homologs.

Table 2 Concentrations of spike solutions for batch, kinetics, and column studies.

Isotope	HCl	HNO_3
^{73}As	2 M	2 M
^{75}Se	11 M	0.01 M
^{197m}Hg	2 M	2 M
^{212}Pb	2 M	2 M
^{210}Po	11 M	0.01 M

For the batch studies, 5 to 15 mg of pre-filter resin was weighed to a centrifuge tube (15 mL). The resin was pre-equilibrated with 1 mL acid (HCl or HNO_3; 0.001 M to conc.) by mixing on an orbital shaker for 30 minutes. A 20 µL spike of acid (see Table 2) containing the isotope of interest (~40 to 100 cps) was added to each sample. Samples were mixed for 1 hour, during which time each sample was counted with an HPGe detector for 30 s to 60 s until there were >2000 counts in the photopeak of interest. Immediately after mixing, each sample was filtered with a 0.45 µm PTFE syringe filter. From the filtered solutions, a 720 µL aliquot was removed and diluted to 1020 µL with de-ionized water to maintain

the geometry of the initial sample. These samples were counted on the same HPGe detector and in the same geometry as the initial sample for a period of 60 s to 600 s (based on the activity levels), until there were >500 counts in the photopeak of interest. Studies with ^{210}Po were conducted in the same manner, except three counting standards were prepared alongside the samples and, after filtering, the aliquot (720 µL) was added directly to an LSC vial with the cocktail. The sample aliquots and standards were counted for a sufficient time to obtain a 2 σ uncertainty (2S%) of ~5%. All batch studies were completed in duplicate.

The weight distribution ratio (D_w, ml g^{-1}) was determined from the initial activity of the sample (A_0), the final activity of the sample (A_s), the acid volume (V, mL) and the weight of the resin (W, g) as shown in Eq. 1 [33] [34]. For the studies with ^{210}Po, A_0 was determined from the average of the three counting standards rather than the initial activity of each sample. By removing a standard aliquot from each sample post-filtration (and subsequent dilution to the initial sample volume), any loss of liquid during the filtration process is corrected for (as only the dilution factor and the activity of the diluted aliquot are necessary to calculate A_s) while still maintaining a consistent geometry for gamma-ray spectrometry.

$$D_w = \frac{A_0 - A_s}{A_s} \times \frac{V}{W} \quad (1)$$

Kinetics Studies

Kinetics samples were prepared in the same manner as in the batch study with 5 to 15 mg of resin pre-equilibrated with 1 mL acid, with the concentration chosen based on the batch study data. The spike solutions were identical to the batch studies, and each sample was mixed for a specific period of time before rapidly filtering. As before, a 720 µL aliquot was removed from the filtered solution and either diluted to 1020 µL with de-ionized water (for HPGe measurements) or prepared in Ulitma Gold AB cocktail (for LSC counting). For all measurements, three counting standards were prepared appropriately alongside the samples for both HPGe and LSC measurements.

Column Studies

Column studies were performed to demonstrate the retention of selenium, polonium, and mercury. All columns were performed with 2 mL pre-packed pre-filter resin cartridges and run using an Eichrom 12-hole polycarbonate vacuum box with a pressure regulator; the eluent flow rate was ~1 mL/min (~5 mmHg). Each column was washed with 8 mL of the same solution as the load solution before elution.

Two column studies were performed with ^{197m}Hg. For a column study in HCl, a load solution of 1 mL 0.07 M HCl (containing ^{197m}Hg) was prepared. The prepared pre-filter column was loaded followed by elution with 5 mL 0.07 M HCl, then 10 mL conc. HCl; all fractions were 1 mL. A separation of ^{73}As and ^{197m}Hg was performed from HNO_3 with a 2 mL load solution in 0.2 M HNO_3. The load solution was eluted on a prepared column followed by 10 mL 0.2 M HNO_3 and 10 mL conc. HNO_3; all fractions were 2 mL. For both of these columns, all fractions were counted immediately after elution with an HPGe detector in the same geometry as the load fraction.

The next column study was performed with a load solution of ^{73}As and ^{75}Se in 2 mL 10 M HCl. The column was eluted with 10 M HCl (12 mL), 8 M HNO_3 (10 mL) and 1% NaCl (10 mL); all fractions were 2 mL. As before, all fractions were counted with an HPGe detector in the same geometry as the load fraction.

Two column studies with ^{210}Po in HCl were performed. The load solutions were prepared in 1 mL 4 M HCl. Both columns were first eluted with 5 mL 4 M HCl followed by 10 mL HNO_3 (0.01 M or conc.). All fractions were collected in 1 mL increments, and, after elution, each fraction was transferred to an LSC vial with cocktail for LSC counting. Counting standards were prepared alongside the load solutions, as in the batch studies.

For the final column studies with ^{212}Pb and ^{210}Po, the load solutions were prepared in 2 mL acid (0.4 M HCl and 10 M HCl). Each column was eluted with 10 mL of the same solution as the load solution followed by 10 mL of NaCl or 8 M HNO_3 to attempt to strip ^{210}Po. All fractions were 2 mL. Each fraction was first counted with gamma spectroscopy in the same geometry as the load solution to measure the ^{212}Pb activity. Then the fractions were

transferred to LSC vials with cocktail and allowed to decay for 2 weeks before LSC counting was performed to determine the activity of ^{210}Po. The decay period eliminated any signal from ^{212}Pb (or its daughters) to make the analysis simpler. Three standards were made with both with ^{212}Pb and ^{210}Po and three were made with only ^{210}Po to aid in determining when the activity contribution from ^{212}Pb (and daughters) was eliminated.

Results and discussion

The results for the batch studies with pre-filter resin are shown in Fig. 1 (a and b); the error is from the standard deviation of two measurements. The lower limit ($D_w \sim 0.1$) for measurement is based on the inherent errors associated with the weight of the resin per sample and counting statistics, which cause large variations at values near zero. There was no extraction of ^{73}As or ^{212}Pb in HCl or HNO_3, and no data is shown for these isotopes.

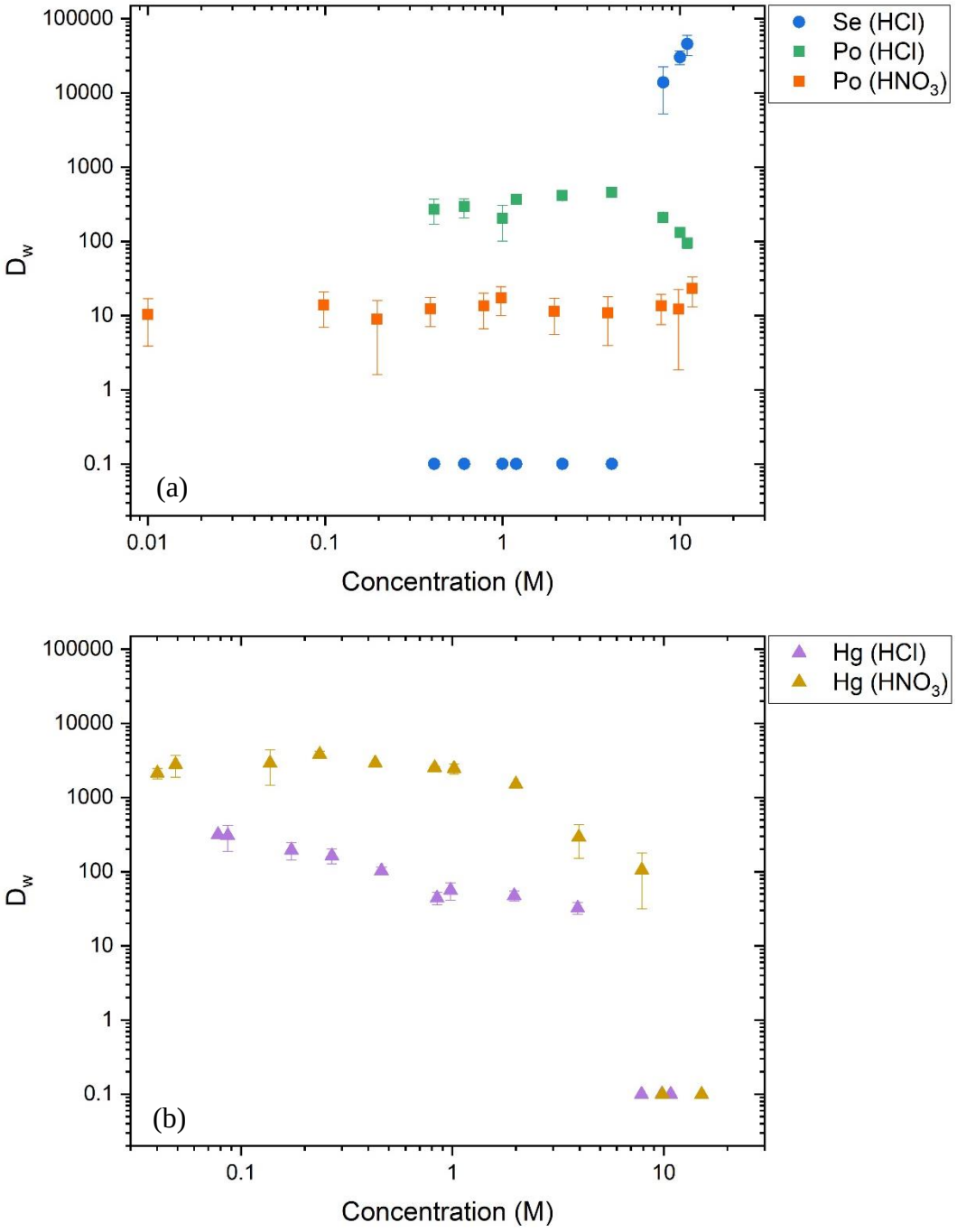

Fig. 1 Batch uptake on pre-filter resin in HCl and HNO_3 for ^{75}Se and ^{210}Po (a) and ^{197m}Hg (b). Error is from the standard deviation of two measurements. There was no uptake of ^{75}Se in HNO_3, or ^{73}As and ^{212}Pb in HCl or HNO_3, therefore no data points are shown for these experiments.

The exact mechanism for the extraction for any of these isotopes is difficult to identify without thorough speciation studies as well as characterization of the pre-filter resin material, however, the most plausible extraction mechanism would be via interaction with the ester group of the acrylic plastic, which could act as a neutral, oxygen-based extraction group. Mercury(II) extracts from both HCl and HNO_3 solutions with higher extraction at low concentrations and decreasing extraction as the concentration increases with no extraction at the highest concentrations. The magnitude of extraction is greater in HNO_3 (peak D_w ~4000) than HCl for all concentrations (peak D_w ~300). In HCl, Hg^{2+} forms $HgCl_2$ at low concentrations (<0.1 M HCl) while anionic forms, $HgCl_3^-$ and $HgCl_4^{2-}$, exist at higher concentrations [35]. In HNO_3, an anionic complex ($Hg(NO_3)_4^{2-}$) forms at lower concentrations, neutral complexes are present at higher concentrations [29] [36]. As pre-filter resin extracts mercury from both acids at low concentrations, the charge on the mercury complex is not the major factor in the extraction. The mechanism is likely more covalent in nature, especially since mercury is a soft metal that readily forms organic species, but it may be more complex than a simple neutral species extraction and the solvation and counterion may play a significant role.

Polonium(IV) forms anions in HCl solutions at concentrations >0.5 M [28] [37]. It extracts well at all concentrations studied (D_w ~300) with a slight decrease at high concentrations. The trend is somewhat similar to Hg^{2+} but the decrease at high concentrations is not as extreme, and it does not decrease to negligible uptake. The extraction of polonium in HNO_3 is much lower than that in HCl, with minor extraction (D_w ~10) at all concentrations. In HNO_3, an anionic form also dominates ($Po(NO3)_6^{2-}$) [28]. As there is no change to speciation, it is likely changes in solvation or the counterion concentration that are driving the decrease in extraction at high concentrations. Polonium is a soft metal ion, like mercury, though whether it extracts via a similar mechanism or not cannot be identified based on these studies. However, as its lighter chalcogen homologs (selenium, tellurium) are well-known to extract on plastic materials [38], the uptake was expected.

The behavior of selenium was extremely different than its heavier homolog (polonium) with extremely high extraction (D_w ~ 40,000) only in high concentrations (>8 M) HCl with no extraction at lower HCl concentrations or any concentrations of HNO_3. Unlike mercury

239 and polonium, which are metals, selenium is a non-metal and even more prone to covalent,
240 organic-type interactions. The extraction of selenium was expected as it is well known to
241 retain in finely divided plastics [39] [38], including other resin materials such as XAD-2
242 [40] and XAD-7 [13], from HCl solutions. In dilute HCl, Se^{4+} is expected to be complexed
243 as selenous acid (H_2SeO_3) [41]; at high concentrations the speciation is not well established
244 and multiple species have been proposed including $SeOCl_2$ [42], $SeCl_4$ [42], $SeCl_6^{2-}$ [43]
245 [44], and H_2SeOCl_4 [45]. In nitric acid, both Se^{4+} and Se^{6+} are expected, they form selenous
246 acid (H_2SeO_3) and selenic acid (H_2SeO_4), respectively, and do not seem to interact with the
247 resin [46].

248 The lack of extraction for arsenic was expected as it has been demonstrated in the past to
249 have no uptake on XAD-7 resin, another untreated, acrylic resin material [13]. Under some
250 conditions, lead is able to retain on acrylic materials, however, often these are more
251 complex materials than a simple polymer and this previous work has been conducted at
252 higher pH values than studied in this work [47] [26] [48]. In the acidic conditions in this
253 work, there was no retention of lead.

254 The results for the kinetics studies are shown in Fig. 2. As there was no significant
255 extraction of ^{210}Po in HNO_3, and no extraction of ^{75}Se, these isotopes were only studied in
256 HCl. The acid concentration for each kinetics study was chosen based on the batch study
257 data (Fig. 1), with each isotope studied in a concentration where the extraction was high.

258 The extraction of polonium is rapid with high extraction (D_w ~100) in under 1 minute.
259 Equilibrium conditions appear to be established by 15 minutes. Mercury is extracted
260 rapidly in HNO_3, with high extraction at 5 minutes, but equilibrium is not reached until ~6
261 hours have elapsed. In HCl, the extraction of mercury takes much longer, and no clear
262 equilibrium value is achieved in ~24 hours. Selenium reaches a high extraction in 5
263 minutes, but it did not reach a clear equilibrium extraction in three hours, and it was not
264 studied for longer as is not redox stable for extended periods of time.

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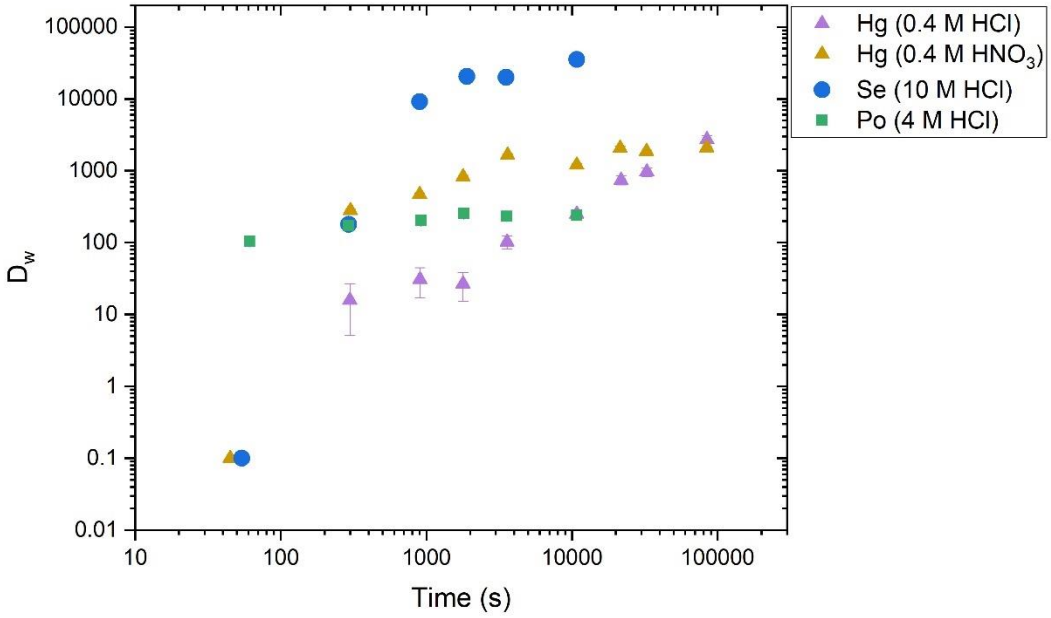
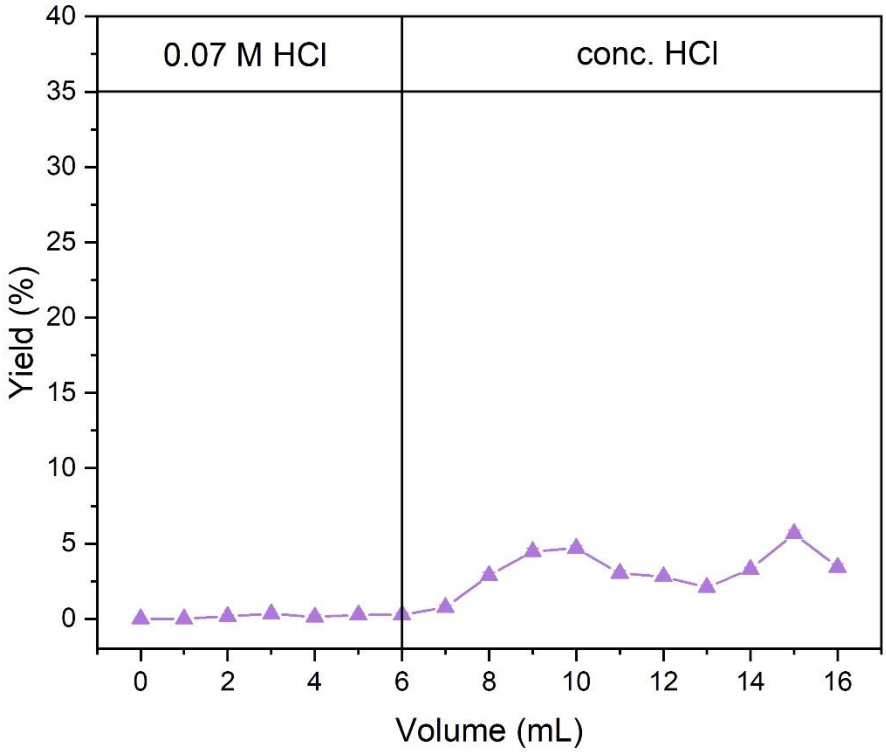


Fig. 2 Uptake kinetics of ^{75}Se, ^{210}Po and ^{197m}Hg on pre-filter resin. Error is statistical counting error.

With D_w values >100 in under 5 minutes for polonium and selenium in HCl and mercury in HNO_3, the retention of these elements on pre-filter resin may impact their recovery in conventional chemical separations when pre-filter resin is used to remove organic materials. This could lead to unexpected losses in the development of chemical procedures. To demonstrate that significant uptake is feasible under realistic solution conditions, numerous column studies were performed.

The results for columns with ^{197m}Hg are shown in Fig. 3 and Fig. 4. From both HCl and HNO_3 solutions, ^{197m}Hg can be retained from dilute acid. From dilute HCl (Fig. 3), there is some bleeding (~1%) of mercury from the resin, which was expected as the uptake kinetics are slow. The total recovery in conc. HCl is low (33.1 ± 0.6%), possibly due to slow desorption kinetics. The uptake from HNO_3 was much higher in the batch studies, and with faster kinetics, and there was no bleeding from dilute acid (Fig. 4). The high uptake enables a separation of ^{197m}Hg from ^{73}As with high yields for both isotopes, 109 ± 11% and 94 ± 4%, respectively, and no detectable ^{197m}Hg in the arsenic fractions (or ^{73}As

283 in the mercury fractions). Mercury is recovered quantitatively with conc. HNO_3, unlike
284 conc. HCl, making high yield separations possible.



285 **Fig. 3** Retention of ^{197m}Hg on pre-filter resin from 0.07 M HCl. Error is statistical counting
286 error; most error bars are smaller than the data points. Lines are to guide the eye.

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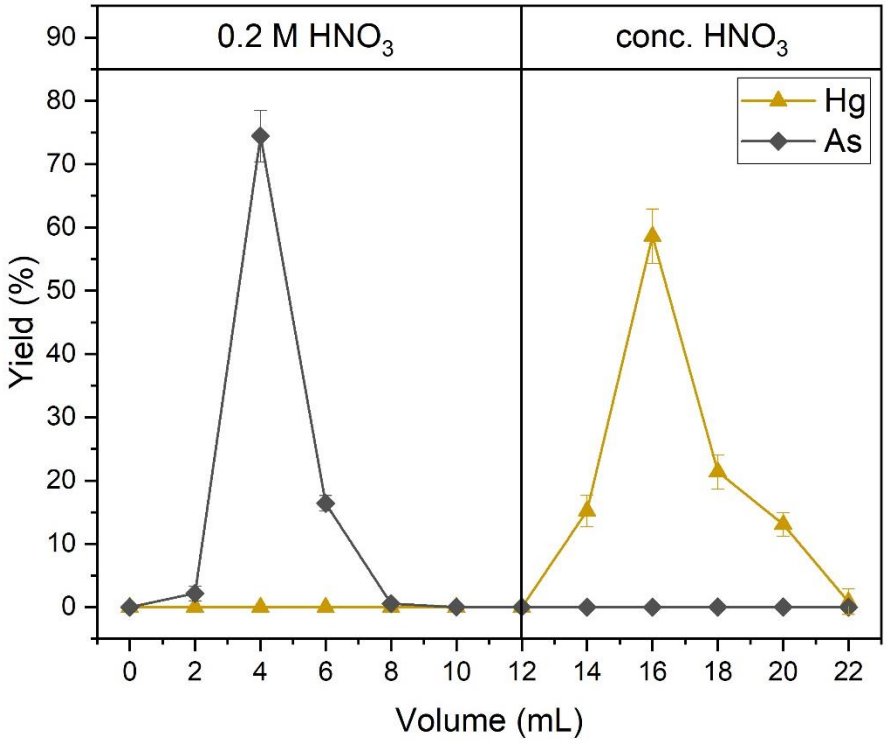

Fig. 4 Column separation of ^{73}As and ^{197m}Hg on pre-filter resin. Error is statistical counting error; most error bars are smaller than the data points. Lines are to guide the eye.

The retention of selenium is sufficient to allow for separations of selenium and arsenic using pre-filter resin from 10 M HCl (Fig. 5). The yield for arsenic is very high (99 ± 6%), and there was no detectable selenium in the arsenic fractions. However, selenium is not readily stripped from the resin with only a small amount (<1%) bleeding off in each fraction in either strongly acidic (8 M HNO_3) or near neutral conditions (1% NaCl, pH ~5.5). Difficulty in recovering selenium has been observed previously on other extraction chromatography resins [13] [40]; to fully explain the irreversible extraction, speciation and desorption kinetics studies would be needed. A column like this may be useful as a final cleaning step for radioarsenic production to remove organic impurities as well as trace selenium, particularly after solvent extraction steps as in Ref. [43] for example.

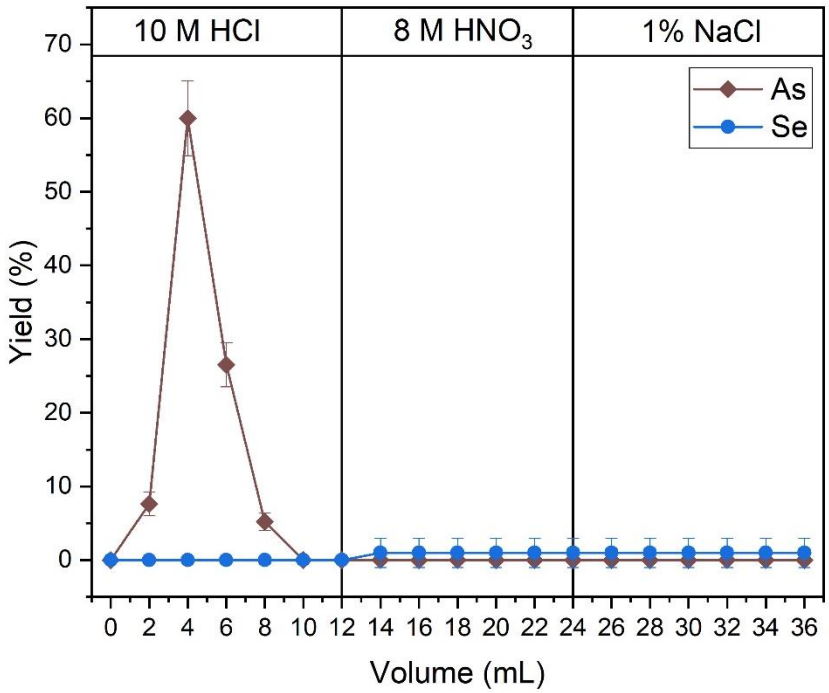

Fig. 5 Column separation of ^{73}As and ^{75}Se on pre-filter resin. Error is statistical counting error; most error bars are smaller than the data points. Lines are to guide the eye.

Like selenium, polonium is not readily stripped from pre-filter resin once retained. This is demonstrated in Fig. 6, which shows the result from two separate column experiments. For each, polonium was retained in 4 M HCl and then eluted with HNO_3. The yield was low with both 0.1 M HNO_3 and conc. HNO_3, 50 ± 2% and 37 ± 3%, respectively.

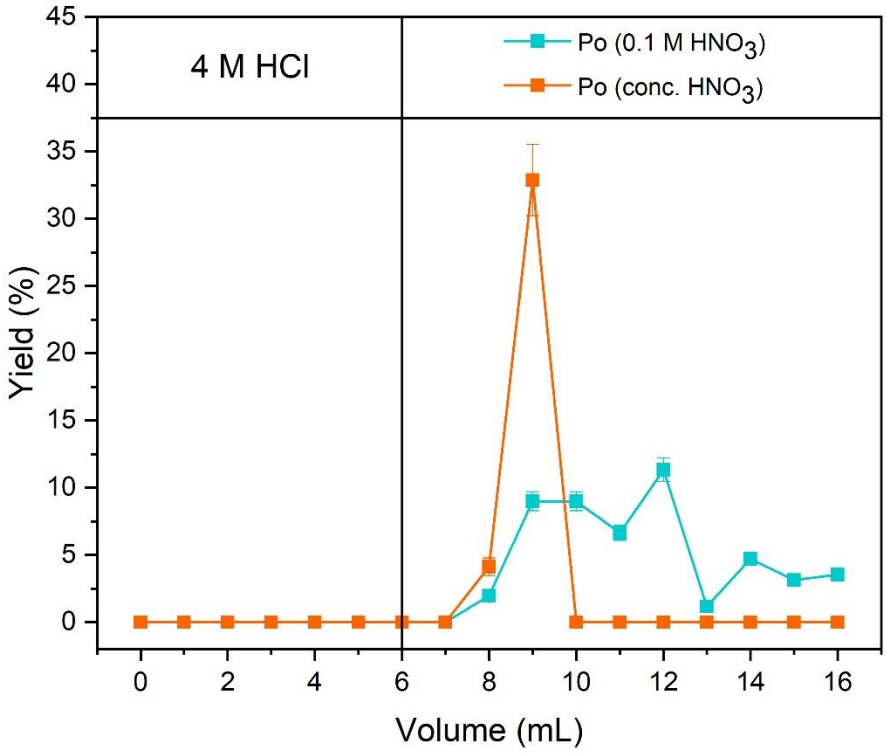

Fig. 6 Retention of ^{210}Po on prefilter resin from 4 M HCl. Two separate column experiments are shown with elutions of 0.1 M HNO_3 and conc. HNO_3. Error is statistical counting error; most error bars are smaller than the data points. Lines are to guide the eye.

Further studies with polonium were performed to demonstrate separations of ^{210}Po and ^{212}Pb (Figs. 7 and 8). As ^{210}Po was well-retained from all HCl concentrations in the batch studies, see Fig. 1 (a), the load solution for each of these columns was a different concentration of HCl to demonstrate the retention from a variety of concentrations. Two different eluents were tested as well, 8 M HNO3 and 1% NaCl, to determine in the polonium elution could be improved as compared to the previous columns (Fig. 6), but neither performed as well as 0.1 M HNO_3. The first polonium/lead separation is shown in Fig. 7, the load solution was 0.4 M HCl. The yield for ^{212}Pb was 95 ± 4% with no detectable ^{210}Po, but the recovery of polonium was negligible with an 8 M HNO_3 eluent. A second column with a load solution of 10 M HCl is shown in Fig. 8. As before, the ^{212}Pb yield is high (95 ± 3%) and the elution of ^{210}Po was minimal with 1% NaCl. As the separation of ^{210}Po from ^{210}Pb is necessary for purification of the ^{238}U decay daughters, this separation

may be useful for geochemical applications, although only for applications where recovery of ^{210}Po is not necessary.

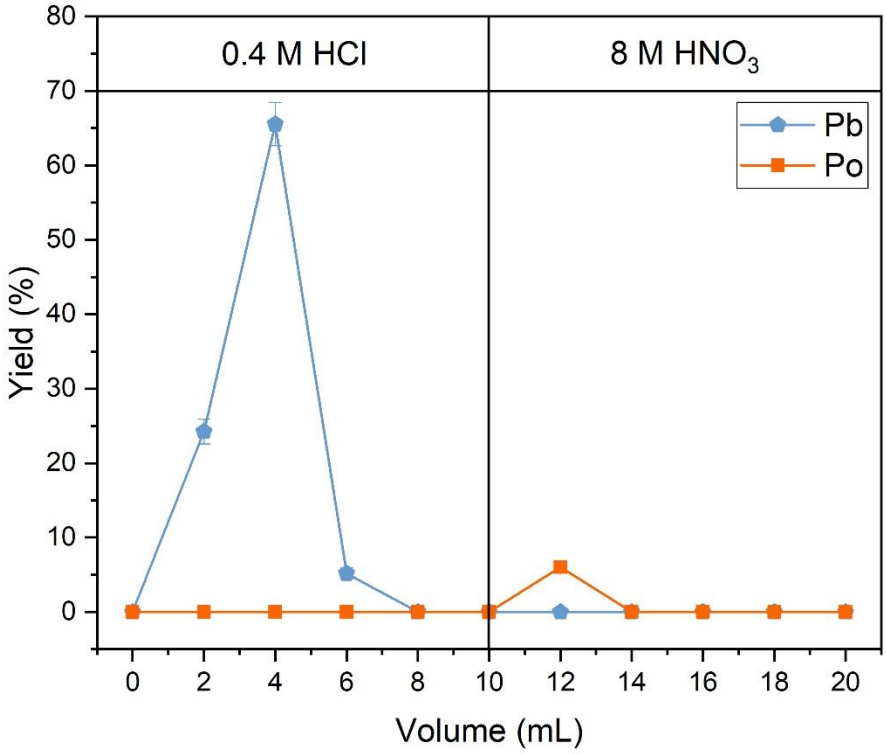

Fig. 7 Column separation of ^{212}Pb and ^{210}Po on pre-filter resin from 0.4 M HCl. Error is statistical counting error; most error bars are smaller than the data points. Lines are to guide the eye.

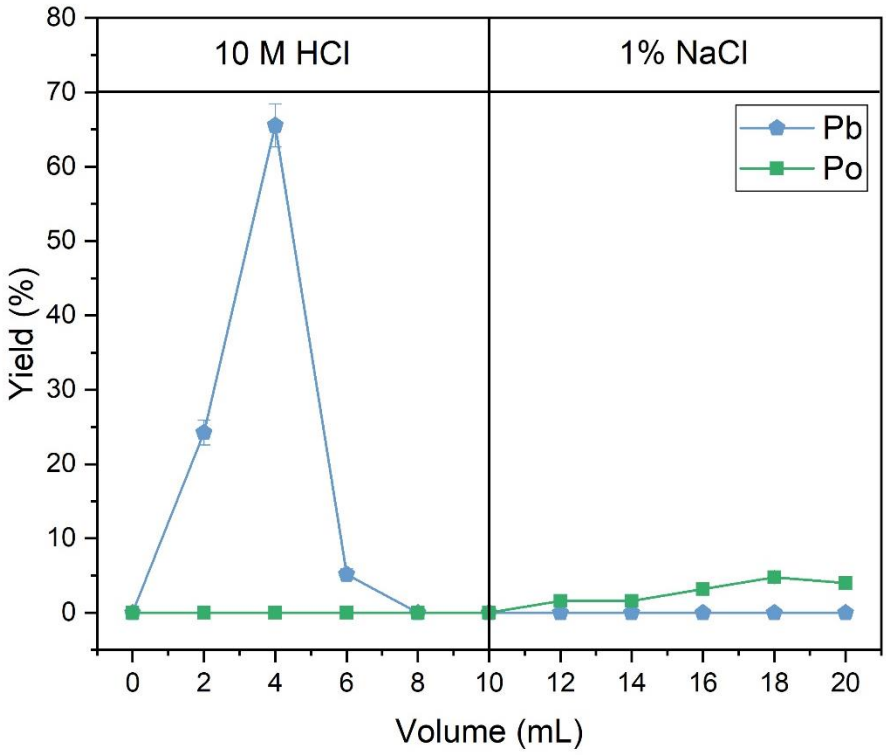

Fig. 8 Column separation of ^{212}Pb and ^{210}Po on pre-filter resin from 10 M HCl. Error is statistical counting error; most error bars are smaller than the data points. Lines are to guide the eye.

Conclusions

The uptake of ^{73}As, ^{75}Se, ^{197m}Hg, ^{212}Pb and ^{210}Po on Eichrom pre-filter resin was studied in HCl and HNO_3 solution. There is significant uptake of mercury in both acids at lower concentrations, and negligible uptake at high concentrations. Polonium is also extracted from both acids, though there is only minor uptake from HNO_3. Selenium has extremely high uptake in high concentration HCl solutions and no uptake from HNO_3. Neither lead nor arsenic extract at any concentration. The extraction mechanism cannot be elucidated from these studies, but it is likely a covalent-type interaction as the charge on the species present does not seem to affect the uptake. Further studies, as well as material characterization, would be needed to determine the exact mechanism, particularly as pre-filter resin is proprietary and the technical documents from Eichrom and Triskem do not provide the exact composition.

The retention of selenium, polonium and mercury on pre-filter resin is an important consideration for designing chemical purification processes for these elements. Under realistic column conditions, all three elements can be retained quantitively from common mineral acid solutions. Furthermore, it is difficult to strip selenium and polonium once retained on the resin, which would contraindicate using this common resin material with these elements in HCl solutions. This uptake has not been characterized in the literature previously, and, as pre-filter resin is sold as "inert", it may not be common in all laboratories to rigorously blank procedures involving this resin. However, neglecting to consider this uptake could lead to high losses, and introduce unexpected sources of error into procedures.

Due to the high retention of selenium, mercury and polonium, column separations are feasible with pre-filter resin. Arsenic-73 can be separated from ^{197m}Hg with high yields and high radiopurity in HNO_3. Similarly, ^{73}As can be readily separated from ^{75}Se, and ^{212}Pb separated from ^{210}Po, but with high losses of ^{75}Se and ^{210}Po in these columns. These columns may be useful for mercury separations, as it can be eluted readily in conc. HNO_3. While selenium is not easily recovered once retained, pre-filter resin may be a good option for a final cleaning steps in chemical procedures to produce arsenic isotopes, as trace organics from previous chemical steps could be easily removed alongside any remaining selenium, which is a common contaminant in the production of arsenic isotopes [24].

It is important to understand the uptake behavior of these elements, and others, under common chemical conditions to identify potential sources of error or losses in the development of chemical procedures. As extraction chromatography resins are marketed for separations for a wider and wider range of metal ions with less well-charactered extraction chemistry, such as selenium and other p-block elements, it is critical that blank studies are performed to ensure that "inert" materials, like pre-filter resin, are not affecting the chemical separations.

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Ethics Declarations

Conflict of Interest

The authors declare that there is no conflict of interest.

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