Separation of Technetium
from Nuclear Waste Stream Simulants

A Report by

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ABSTRACT

Members of the Strauss research group at Colorado State University acquired equipment and instrumentation necessary to carry out this project, including a Perkin-Elmer P-400 ICP-AES spectrometer. All members of the research team were trained in the proper protocols, procedures, and safeguards necessary to carry out this project. We evaluated several colorimetric assays for ReO$_4^-$, and discovered that all were flawed. We evaluated atomic absorption spectroscopy as a technique to determine sub-millimolar concentrations of ReO$_4^-$, and discovered that it is not sensitive enough for our use. However, we discovered that ICP-AES can be used to determine concentrations of ReO$_4^-$ down to 0.25 ppm. We next determined that ReO$_4^-$ can be quickly extracted (10 minutes or less) from aqueous HNO$_3$ using the commercial extractant Aliquat-336 nitrate diluted with 1,3-diisopropylbenzene. Higher concentrations of extractant led to higher values of $K_d$ (the distribution ratio). $K_d$ was lower as the nitrate concentration of the medium increased, and was also lowered by increasing the acidity at constant nitrate ion concentration. We performed parallel studies with TcO$_4^-$, determining that $K_d$(ReO$_4^-$) and $K_d$(TcO$_4^-$) track similarly as the conditions are changed. A considerable effort was made to prepare substituted pyridium nitrate salts that are soluble in organic solvents so that these could be used as alternate extractants. Over twelve different compounds were made and purified. However, in all cases but one, the salts were also soluble to some extent in the aqueous phase, significantly limiting their usefulness as extractants for our purposes. Many of the new extractant salts would partition between the organic solvent and water so that 10% of the extractant salt was in the aqueous phase. Only 1-methyl-3,5-didodecylpyridium nitrate (prepared from a sample of the chloride salt, which was prepared by Professor Richard Bartsch's group at Texas Tech University) did not show any measurable solubility in water. However, this compound was not as good an extractant as Aliquat-336. A considerable effort was also made to find suitable alternative solvents to 1,3-diisopropylbenzene. Several ketone solvents with flash points above 60°C were tested, and two of these, 2-nonanone and 3-nonanone, were superior to 1,3-diisopropylbenzene as a diluent (i.e., significantly higher $K_d$ values were observed).
STATEMENT OF WORK
(written October 1993; updated July 1994)
Separation of Technetium from Nuclear Waste Stream Simulants

INTRODUCTION

Approximately 5,600 kg of technetium (Tc) are present in the Hanford waste tanks, primarily as pertechnetate (TcO$_4^-$), which is a very mobile species in the environment. This characteristic, along with its long half-life ($^{99}$Tc, $t_{1/2} = 213,000$ a) makes technetium a major contributor to the long-term hazard associated with Hanford's low level waste (LLW) form, grout. For a variety of reasons, current grout technologies are incompatible with the presence of technetium. Instead, the *separation of technetium* from the LLW stream and then *vitrifying it* along with the high level waste components is the best alternative. In the near term, Initial Pretreatment Modules (IPMs) will be required to treat waste streams in order to mitigate safety concerns and to generate tank capacity. Since the IPM effluent is destined for the grout plant, complex pretreatment processes such as the "Clean Option" will require technetium separation from both acidic and caustic waste streams. A leading candidate technology for separating technetium is *liquid phase solvent extraction*. This Statement of Work details the research that the Strauss research group in the chemistry department of Colorado State University (CSU) will carry out to evaluate, develop, and improve this technology.

REQUESTED RESEARCH

The Strauss research group in the chemistry department of CSU will investigate the solvent extraction behavior of salts of the perrhenate (ReO$_4^-$) ion, a stable (non-radioactive) chemical surrogate for pertechnetate. These two tetrahedral anions have very similar sizes and potentials.

\[
\begin{align*}
\text{TcO}_4^- & : r(\text{Tc-O}) = 1.711(3) \text{Å} \\
\text{ReO}_4^- & : r(\text{Re-O}) = 1.719(5) \text{Å}
\end{align*}
\]

\[
\begin{align*}
\text{TcO}_4^-/\text{TcO}_2 & : E^o = 0.74 \text{ V} \\
\text{ReO}_4^-/\text{ReO}_2 & : E^o = 0.51 \text{ V}
\end{align*}
\]

\[
\begin{align*}
K_a & = 1.1 \ (\mu = 5) \\
K_a & = 0.52 \ (\mu = 5)
\end{align*}
\]

Sol. (K$^+$, H$_2$O, 25°C) = 0.11 molal

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Commercially available anion extractants, including Aliquat-336®, will be used along with commercially available technical grade solvents, including meta-diisopropylbenzene. The concentrations of perrhenate in the aqueous phase will be chosen to simulate the concentrations of pertechnetate in known waste streams. As the work progresses, known co-contaminants will be added to the aqueous phase in an effort to closely simulate the composition of known waste streams. The exact nature of these results cannot be anticipated. The investigators will be in weekly communication with Drs. Kent Abney and Norman Schroeder as well as other LANL staff. In this way, the CSU investigators will learn about the evolving needs of the Hanford Waste Tank Remediation project, and therefore the lines of experimentation at Colorado State will drift in the direction of LANL and DOE programmatic needs.

The project will be broken down into the following distinct phases. **Phase 1.** Professor Strauss, the principal investigator, will complete an up-to-date literature search and review on solvent extraction methodologies (from both aqueous and non-aqueous media) for pertechnetate and perrhenate. The goal will be to identify promising anion extractants that might be tested, even if these are not commercially available. The P.I. will purchase and install the required equipment and supplies and will train the personnel (the graduate students and the postdoc). The team of investigators will complete an assessment of analytical techniques for the quantitative determination of sub-millimolar concentrations of ReO₄⁻ in both aqueous and non-aqueous media. The analytical techniques evaluated will include atomic absorption spectroscopy, inductively coupled plasma atomic emission spectroscopy, UV-VIS (electronic) spectrophotometry, and mass spectrometry. This phase of the project will be completed by the end of the first three months of the sub-contract.

**Phase 2.** The research team will complete a study of the extraction of ReO₄⁻ from acid solution and/or basic solution using Aliquat 336 as the anion extractant and meta-diisopropylbenzene as the non-aqueous solvent. The parameters chosen will parallel those used in a similar study of TcO₄⁻ extraction carried out by Dr. Norman Schroeder in INC-12. As the apparent necessity warrants and as time permits, this line of investigation will include the behavior of [OH⁻], [NO₃⁻], [NO₂⁻], [HCO₃⁻] with the chloride and nitrate forms of Aliquat-336. The quantitative data of interest are the values of the distribution coefficients (Kₐ) and the solubility of the anion extractant in the aqueous phase. These data will allow a determination to be made regarding the efficacy of perrhenate as a stable (non-radioactive) surrogate for pertechnetate as far as proven solvent extraction methodologies are concerned. This phase of the project will be completed by the end of the first six months.
Phase 3. The research team will begin a study of alternate non-aqueous solvents and alternate anion extractants. The emphasis will be on solvents that are not aromatic hydrocarbons, not chlorinated hydrocarbons, and that have flash points greater than 60°C. As far as anion extractants are concerned, some will be purchased from commercial sources, some will be supplied by scientists at LANL, and some will be synthesized in our laboratory. Our goal will be to improve the current extraction system involving Aliquat-336 and meta-diisopropylbenzene by at least a factor of 10 in $K_d$ without sacrificing selectivity for $\text{TcO}_4^-$ from other fission products and without creating a new waste stream that is environmentally problematic. Variables will include temperature, contact time, pH, [NO$_3^-$], [NO$_2^-$], and [HCO$_3^-$]. This phase of the project will be started before the end of the first nine months. It is open ended, since the number of new extraction systems is not limited, and for this reason this phase may not be "complete" by the end of the sub-contract.

Phase 4. The research team will begin a study of alternatives to re-extraction of ReO$_4^-$ into aqueous acid for concentration, removal, and storage. The goal is to develop one or more methodologies that will allow ReO$_4^-$ (and ultimately TcO$_4^-$) to be isolated in concentrated form directly from the non-aqueous solvent. This would eliminate the production of a high-volume waste stream (currently 8M nitric acid) and could conceivably lead to the recycling of the anion extractant. Several possible methods, including chemical precipitation, chemical reduction, and electrochemical reduction (with precipitation) will be explored. This phase of the project will be started before the end of the first twelve months and, if fruitful, could possibly become an ongoing project, since this is a very important aspect of the DOE's technetium waste problem.

The four phases of proposed experiments above are very ambitious. It is given as an indication of the direction that the research will take. It is anticipated that some of the activities will not be able to be explored as completely as others. Furthermore, as the project proceeds, and as the Strauss group communicates with the Los Alamos group, some of the proposed experiments might lose their urgency. However, the identification, evaluation, and development of alternative solvent extraction methodologies for perrhenate (pertechnetate) will remain the primary objective.

In addition to supplying the Strauss research group with new anion extractants, the INC-12 group at LANL will supply a Macintosh Centris 650 8/230 computer, including the latest versions of the software Word, Excel, Kalaidagraph, and Chemdraw Plus, that will be used for data collection, graphical analysis of data, literature searching (a modem pool exists via the chemistry department network), figure preparation, and report and manuscript preparation. This computer
will remain in Professor Strauss' lab at Colorado State University for the duration of the subcontract. A printer is not required, since one is available to the Strauss group at CSU.

RESULTS

The exact nature of the results of the experiments outlined above cannot be anticipated. Hence, the expectations will be nothing more than the results of the experiments. The abilities and judgement of the investigators will be relied on to develop the most fruitful lines of experimentation.

DELIVERABLES

1. A report on Phase 1 of the project will be submitted to LANL by June 1, 1994.
2. A report on Phase 2 of the project will be submitted to LANL by July 1, 1994.
3. A report on Phase 3 of the project will be submitted to LANL by Sept. 1, 1994.
SECTION I — LITERATURE REVIEW

We have reviewed the literature related to this project, especially with respect to the extraction of TcO₄⁻ and ReO₄⁻ from aqueous solution using organic extractants and solvents. The database CAS Online was searched during July 1993 and April 1994. Our review appears in this Milestone as a 35-page appendix starting on page 16.

SECTION II — EQUIPMENT INSTALLATION AND PERSONNEL TRAINING

During the first phase of the project, major equipment, glassware, and supplies were purchased and installed in Professor Strauss' laboratory. The equipment included a Perkin-Elmer P-400 inductively-coupled-plasma atomic emission spectrometer (ICP-AES), a Büchi rotary evaporator, a Barnstead Nanopure water purifier, an Orion pH meter, a LabLine microprocessor shaker bath, a Macintosh Quadra 650 computer, and a vacuum system for the synthesis of new extractants.

The personnel who have worked on this project all have degrees in chemistry. They are:
- Professor Steven H. Strauss, P.I., Ph.D. 1979, Northwestern University
- Dr. M. Dawn Van Seggen, Ph.D. 1994, Colorado State University
- Ms. Jennifer Clark, B.S. 1993, University of Colorado at Boulder
- Ms. Kristina M. Rohal, B.S. 1993, Bethany College
- Mr. Jeffrey J. Rackal, B.S. 1990, Clemson University
- Mr. Tom Barbarich, B.S. 1991, Wayne State University
- Mr. Juston Rockwell, B.S. 1991, Fort Lewis College
SECTION III — QUANTITATIVE DETERMINATION OF ReO$_4^-$

During the summer of 1993 (before the contract began), Professor Strauss and Ms. Butoi evaluated several colorimetric (spectrophotometric) assays for ReO$_4^-$, most notably those involving simultaneous reduction of rhenium and complex formation with thiocyanate anion. The major references for these assays are given below:


We determined that none of the prescribed methods gave reproducible and precise results. All methods were flawed, primarily due to incomplete conversion of all of the rhenium present to a single species with a known extinction coefficient. No further attempts were made to improve the spectrophotometric procedures.
We evaluated atomic absorption (AA) spectroscopy as a technique to determine sub-millimolar concentrations of ReO$_4^-$.
Rhenium cannot be determined using graphite furnace AA, which is normally one to two orders of magnitude more sensitive than standard AA, because it forms a refractory carbide.
We prepared samples and traveled to the Perkin-Elmer facility in Denver, CO, where, with the help of a member of their technical staff, we determined that the lowest concentration of rhenium (in the form of ReO$_4^-$) that we could reproducibly and precisely measure was approx. 100 ppm (1 mM ReO$_4^-$ = 1,800 ppm rhenium). Since we expect to develop superior extractants in the course of this project that could lead to residual concentrations of ReO$_4^-$ below 1 ppm in the raffinate, we decided that AA spectroscopy was not suitable for this project.

We evaluated ICP-AES on another occasion, also with the help of the Perkin-Elmer technical staff. Reproducible and precise data were obtained for concentrations of rhenium (in the form of ReO$_4^-$) down to 0.25 ppm.

On the basis of this evaluation, we purchased a used (one-year old) ICP atomic emission spectrometer from Perkin-Elmer in November 1993.

Along with the two sections above, this completed Phase 1 of the project.

**SECTION IV — EXTRACTION OF ReO$_4^-$ USING ALIQUAT-336**

During the next phase of the project, we studied the extraction of a 1.00 mM solution of KReO$_4$ in 5.00 M nitric acid using the commercial extractant Aliquat-336 nitrate (purchased from Aldrich Chemical Co.) dissolved in 1,3-diisopropylbenzene (DIPB; 96%, also purchased from Aldrich). The extractant is a viscous liquid. The sample purchased contained a small amount of a light colored precipitate. Solutions of the extractant in DIPB also contained a small amount of precipitate. Aldrich has informed us that they are discontinuing Aliquat-336 salts because of the formation of the precipitate, which they have not characterized. Another supplier will have to be found, and the formation of the precipitate remains a problem.

Standard samples of KReO$_4$ in 5.00 M nitric acid were prepared and were used to create ICP-AES calibration curves. Two such curves, created using freshly prepared perrhenate samples on two consecutive days, are shown on the next two pages (Figures 1-2). The agreement from day to day is more than adequate for the concentration range chosen (0-1 mM ReO$_4^-$). We have determined that standard samples of KReO$_4$ in nitric acid are stable for many weeks. Nevertheless, we plan to prepare fresh calibration standards on a regular basis.
Figure 1. ICP Intensity vs. [ReO₄⁻] (i.e., a calibration curve) for extraction of ReO₄⁻ from aqueous 5M HNO₃ into diisopropylbenzene containing 0.2 M Aliquat-336 nitrate
Figure 2. ICP Intensity vs. [ReO₄⁻] (i.e., another calibration curve) for extraction of ReO₄⁻ from aqueous 5M HNO₃ into diisopropylbenzene containing 0.2 M Aliquat-336 nitrate
In a typical extraction experiment, 20 mL of aqueous perrhenate solution was mixed with 20 mL of an Aliquat-336 nitrate/DIPB solution and shaken for a prescribed amount of time at 20°C. The phases were separated using separatory funnels and the aqueous raffinate was collected in vials for immediate analysis on the ICP-AES. We found that a third phase was present in all experiments. The top phase was nearly colorless and is presumably mostly DIPB. The middle phase was yellow (neat Aliquat-336 nitrate is yellow), and is presumably a concentrated solution of the extractant in DIPB. The bottom phase was colorless and is presumably the aqueous raffinate. The volume of the middle phase increased as the concentration of extractant in DIPB increased from 0.100 M to 0.840 M. In a report that we received from Dr. Norm Schroeder last year, a plot of TcO$_4^-$ $K_d$ vs. concentration of nitric acid showed that a third phase was present when the acid concentration was 7.5 M and 10.0 M but not at 5.0 M. We have not yet used 1-butanol as a modifier, to eliminate the third phase, in our experiments.

We found that the extractions were complete within 10 minutes: there was no difference in the residual concentration of ReO$_4^-$ after 10, 20, 40, and 106 minutes of shaking at 20°C. Therefore, 20 minutes has been chosen for the shaking time in all subsequent experiments.

The distribution ratio ($K_d$) is defined as the concentration of ReO$_4^-$ in the organic phase(s) (the extract) divided by the concentration of ReO$_4^-$ remaining in the aqueous phase (the raffinate). Since we have directly determined only the latter concentration, $K_d$ values were calculated as follows ([ReO$_4^-$]$_f$ is the final concentration of perrhenate remaining in the raffinate after the extraction is complete):

$$K_d = \frac{1 - [\text{ReO}_4^-]^o}{[\text{ReO}_4^-]_f}$$

For 0.200 M Aliquat-336 nitrate in DIPB, we found $K_d$ to be 0.55 when the ratio of organic:aqueous volumes was 1:1 and 0.68 when the ratio of volumes was 2:1. In principal, the $K_d$ values should not depend on the volumes chosen if the two phases are immiscible. Our values are lower than the $K_d$ of ~1.8 for TcO$_4^-$ measured under the same conditions by Dr. Norm Schroeder last year at LANL.

As expected, we found that $K_d$ increased when the concentration of extractant was increased (for a constant ratio of volumes). The lowest $K_d$, 0.12, was measured when the
concentration of the extractant in DIPB was 0.100 M. The highest $K_d$, 4.0, was measured when the extractant concentration was 0.840 M. These data are displayed in two different ways in graphs shown below and on the next page (Figures 3-4).

\[ \text{[ReO}_4^-\text{]- Conc. (final) vs. Aliquat-336 Conc.} \]

\[ 5\text{ M HNO}_3, 1\text{ mM initial [ReO}_4^-\text{]} \]

![Graph](image)

**Figure 3.** Final aqueous concentration of ReO$_4^-$ vs. concentration of Aliquat-336.
Figure 4. Distribution ratio ($K_d(\text{ReO}_4^-)$) vs. concentration of Aliquat-336.

[ReO4]- Dist. Ratio vs. Aliquat-336 Conc.

5 M HNO3, 1 mM initial [ReO4]-

Aliquat-336 Conc. in 1,3-DIPB (M)
SECTION V — FURTHER STUDIES ON THE EXTRACTION OF ReO$_4^-$

During phase one of this project, we determined that inductively-coupled-plasma atomic emission spectroscopy (ICP-AES) is the optimal technique for determining sub-millimolar concentrations of ReO$_4^-$ in aqueous solution. We began our study of the extraction of ReO$_4^-$ from nitric acid into 1,3-diisopropylbenzene containing 0.2 M of the commercial extractant Aliquat-336$^{\text{®}}$ nitrate (methyltricaprylammonium nitrate). During phase two of this project, we continued to study the extraction of ReO$_4^-$ from various concentrations of nitric acid and from a number of other aqueous "waste stream simulants."

The following experimental procedure was used. Twenty mL of aqueous perrhenate solution (1.0, 5.0, or 10.0 mM KReO$_4$, depending on the preliminary $K_d$ value determined in screening experiments) was mixed with 20 mL of a 0.2 M Aliquat-336$^{\text{®}}$ nitrate (methyltricaprylammonium nitrate) solution in diisopropylbenzene (pure 1,3 isomer or technical grade, which contains 96% of the 1,3 isomer) and shaken for 20 min. at 20°C. The phases were separated using separatory funnels (10 min.) and the aqueous raffinate was collected in either glass or polyethylene vials for analysis on the ICP-AES (Perkin Elmer P400). The distribution ratio ($K_d$) is defined as the concentration of ReO$_4^-$ in the organic phase(s) (the extract) divided by the concentration of ReO$_4^-$ remaining in the aqueous phase (the raffinate). Since we have directly determined only the latter concentration, $K_d$ values were calculated as follows ($[\text{ReO}_4^-]_i$ is the initial concentration of perrhenate in the aqueous layer and $[\text{ReO}_4^-]_f$ is the final concentration of perrhenate remaining in the aqueous layer (the raffinate) after the extraction is complete):

$$K_d = ([\text{ReO}_4^-]_i - [\text{ReO}_4^-]_f) / [\text{ReO}_4^-]_f$$

Our results are summarized in Table I, below. Some of the results are displayed graphically in Figures 5-7, below. The value of $K_d$ drops by a factor of 29 between 0 M and 1 M HNO$_3$ and continues to drop by a factor of 100 between 1 M and 5 M HNO$_3$ (see Figure 1). This is undoubtedly due in large part to competition between ReO$_4^-$ and NO$_3^-$ for the extractant cation, methyltricaprylammonium ion, in the organic phase. The CH$_3$NR$_3^+$/ReO$_4^-$ ion pair in diisopropylbenzene is clearly more stable than the CH$_3$NR$_3^+$/NO$_3^-$ ion pair in this solvent. At 1 M aqueous HNO$_3$ and 1 mM aqueous KReO$_4$, the starting aqueous concentration ratio [NO$_3^-$]/[ReO$_4^-$] was 1,000 yet 98% of the perrhenate ion present was in the organic phase at the end of the extraction. At 5 M aqueous HNO$_3$, only 35% of the perrhenate ions transferred from the aqueous phase to the organic phase.

The hydrogen ion concentration, [H$_3$O$^+$], has a minor effect on $K_d$ when the aqueous concentration of nitrate ion is kept constant at 3 M (see Figure 2). Increasing [H$_3$O$^+$] from 10$^{-7}$ M
Table I. Extraction of ReO$_4^-$ from Aqueous Waste Stream Simulants$^a$

<table>
<thead>
<tr>
<th>aqueous phase</th>
<th>$K_d$</th>
</tr>
</thead>
<tbody>
<tr>
<td>18.3 Mohm water</td>
<td>$1.4 \times 10^3$</td>
</tr>
<tr>
<td>1 M HNO$_3$</td>
<td>49</td>
</tr>
<tr>
<td>1 M HNO$_3$</td>
<td>28$^b$</td>
</tr>
<tr>
<td>2 M HNO$_3$</td>
<td>13</td>
</tr>
<tr>
<td>3 M HNO$_3$</td>
<td>4.3</td>
</tr>
<tr>
<td>4 M HNO$_3$</td>
<td>0.84</td>
</tr>
<tr>
<td>5 M HNO$_3$</td>
<td>0.55</td>
</tr>
<tr>
<td>2 M HNO$_3$/1 M NaN$_3$</td>
<td>6.1</td>
</tr>
<tr>
<td>1 M HNO$_3$/2 M NaN$_3$</td>
<td>11</td>
</tr>
<tr>
<td>3 M NaN$_3$</td>
<td>27</td>
</tr>
<tr>
<td>0.5 M NaOH</td>
<td>$2.8 \times 10^3$</td>
</tr>
<tr>
<td>1 M NaOH</td>
<td>$3.1 \times 10^3$</td>
</tr>
<tr>
<td>2 M NaOH</td>
<td>$3.4 \times 10^3$</td>
</tr>
<tr>
<td>3 M NaOH</td>
<td>$4.3 \times 10^3$</td>
</tr>
<tr>
<td>4 M NaOH</td>
<td>$4.5 \times 10^3$</td>
</tr>
<tr>
<td>5 M NaOH</td>
<td>$6.1 \times 10^3$</td>
</tr>
<tr>
<td>1 M NaOH/1.5 M NaN$_3$</td>
<td>87$^c$</td>
</tr>
<tr>
<td>1 M NaOH/1.5 M NaN$_3$</td>
<td>29$^b$</td>
</tr>
<tr>
<td>1 M NaOH/1.5 M NaN$_2$</td>
<td>$3.3 \times 10^2$</td>
</tr>
<tr>
<td>1 M NaOH/1.5 M NaN$_3$/1.5 M NaN$_2$</td>
<td>76</td>
</tr>
</tbody>
</table>

$^a$ The organic phase was diisopropylbenzene containing 0.2 M Aliquat-336$^\text{®}$ nitrate unless otherwise noted. $^b$ The organic phase was 7.0% w/w 1-octanol in diisopropylbenzene containing 0.2 M Aliquat-336$^\text{®}$ nitrate. $^c$ To within experimental error, the same value ($K_d = 88$) was obtained when the Aliquat-336$^\text{®}$ solution was pretreated by shaking with 1 M NaOH for 24 h.
Figure 5. Plots of $K_d$ vs. $[\text{HNO}_3]$, using two different ordinate scales, for extraction of ReO$_4^-$ from aqueous HNO$_3$ into diisopropylbenzene containing 0.2 M Aliquat-336 nitrate.
Figure 6. $K_d$ vs. [HNO$_3$] for extraction of ReO$_4^-$ from aqueous mixtures of HNO$_3$ and NaNO$_3$ containing a constant 3 M concentration of NO$_3^-$ into diisopropylbenzene containing 0.2 M Aliquat-336 nitrate.
Figure 7. $K_d$ vs. [NaOH] for extraction of ReO$_4^-$ from aqueous NaOH into diisopropylbenzene containing 0.2 M Aliquat-336 nitrate
(0 M HNO₃) to 3 M caused $K_d$ to decrease from 27 to 4.3. This may be due to changes in the relative amounts of anionic ReO₄⁻ and neutral HReO₄ as [H₃O⁺] increases.¹

The value of $K_d$ increases steadily as [OH⁻] increases (see Figure 7). A maximum value of $K_d = 6.1 \times 10^3$ was obtained when [OH⁻] = 5 M. However, the presence of nitrate ion decreased $K_d$ dramatically. When the aqueous solution was simply 1 M NaOH, $K_d$ was $2.8 \times 10^3$. When 1.5 M NaN₂O₃ was also present, $K_d$ was 87. When 1.5 M NaN₂O₂ was also present, the combination of OH⁻, NO₃⁻, and NO₂⁻ lowered $K_d$ to 76. This last result indicates that nitrite ion does not affect $K_d$ significantly when nitrate ion is already present. For an aqueous solution consisting of 1.0 M NaOH and 1.5 M NaN₂O₂, $K_d$ was $3.3 \times 10^2$.

SECTION VI — EXTRACTION OF TcO₄⁻

Professor Strauss and Dr. Van Seggen spent two months in the CST-12 group at LANL (June and July, 1994). During this time, we studied the extraction of TcO₄⁻ from a variety of aqueous "waste stream simulants."

The following experimental procedure was used. A sample of either 2.5 or 3.0 mL of aqueous pertechnetate solution ($1.5 \times 10^{-5}$ M $^{99}$TcO₄⁻, $10^{-8}$ M $^{95m}$TcO₄) was mixed in a thin glass tube with an equal volume of an organic phase containing 0.1 M or 0.2 M extractant and shaken for at least 2 min. at 20°C. The phases were separated by centrifugation (5 min. at 5,000 rpm) and either 1.0 or 1.5 mL of each phase was transferred to a thin plastic tube. The tubes were placed in a gamma ray counting instrument with a NaI(Tl) scintillation detection system (Packard Auto-Gamma® 5530). The number of counts-per-minute (CPM) for each sample and for several blanks (background, BKG) were recorded.

Technetium-95m ($I = +1/2$) decays with a half-life of 61 days by isomeric transition (4%), positron emission (0.4%) and electron capture with gamma emission (>95%).² Seventy percent of all decay events produce a gamma photon of energy 0.2042 MeV.² These are the photons that are counted (the lower and upper limits of photon energies counted by the instrument were set as 0.165 and 0.245 MeV, respectively).

The distribution ratio ($K_d$) is defined as the concentration of TcO₄⁻ in the organic phase (the extract) divided by the concentration of TcO₄⁻ remaining in the aqueous phase (the raffinate). $K_d$ values were calculated as follows (the subscripts $o$ and $a$ refer to organic and aqueous phases, respectively):

$$K_d = \frac{(CPM_o - BKG)}{(CPM_a - BKG)}$$
Our results are summarized in Table II, below. As the concentration of nitric acid in the aqueous phase increased from 1 M to 8 M, $K_d$ decreased by a factor of 100, from 41 to 0.40. A comparison of Aliquat-336 nitrate with the new extractant DDP$^+\text{Cl}^-$ (DDP$^+$ = 3,5-didodecylpyridinium ion) showed the Aliquat salt to be the better extractant in 7.0% w/w 1-octanol in diisopropylbenzene: $K_d$ for 0.2 M Aliquat-336 nitrate was 41 while $K_d$ for $\sim$0.1 M DDP$^+\text{Cl}^-$ was 4.9 ($\text{DDP}^+\text{Cl}^-$ is not very soluble in 7.0% w/w 1-octanol in diisopropylbenzene). Therefore, for equal concentrations of these two extractants, the Aliquat salt would be approximately four times better than DDP$^+\text{Cl}^-$. 

A series of extractions were carried out with an aqueous phase consisting of 1.0 M NaOH and 1.5 M NaNO$_3$. The baseline value of $K_d$ for an organic phase consisting of diisopropylbenzene containing 0.2 M Aliquat-336 nitrate was $1.1 \times 10^2$. (This value did not change when the contact (shake) time was changed from 2 minutes to 5 minutes to 24 hours.) When the organic diluent was changed to 7.0% 1-octanol in diisopropylbenzene, $K_d$ decreased to 59. When an analog of 1-octanol, 2-ethyl-1-hexanol, was used as the diluent with 0.1 M Aliquat nitrate, $K_d$ dropped to 4.0. Clearly, these alcohols must be avoided if high values of $K_d$ are required. When 2,6-dimethyl-4-heptanone (diisobutylketone) was used as the diluent with 0.1 and 0.2 M Aliquat nitrate, $K_d$ increased to $2.3 \times 10^2$ and $3.7 \times 10^2$, respectively. This is a significant increase, and this solvent warrants further study (see Section IV, below). When neat 2,6-dimethyl-4-heptanone was used as the organic phase (no extractant added), $K_d$ was 20. When the organic phase consisted of diisopropylbenzene containing $\sim$0.1 M DPP$^+\text{Cl}^-$, $K_d$ was less than $10^{-3}$. Under these conditions, hydroxide ion is undoubtedly deprotonating the pyridinium ion, and the neutral pyridine does not function as an extractant for TcO$_4^-$.

A series of extractions were carried out with a varying aqueous phase. Each sample contained 1 M NaOH and all but one sample also contained other co-contaminants. The organic phase was 0.2 M Aliquat-336 nitrate in diisopropylbenzene in all cases. The baseline value of $K_d$ when the aqueous phase was simply 1 M NaOH was $6.2 \times 10^2$. When the aqueous phase also contained 1.5 M NaNO$_3$, $K_d$ decreased to $1.1 \times 10^2$. The presence of 0.14 M K$_2$CrO$_4$ in the 1 M NaOH/1.5 M NaNO$_3$ aqueous phase had a negligible effect on $K_d$. This concentration of chromate ion is ten times that present in Hanford tank 240-AN-106. Apparently, 0.2 M Aliquat-336 nitrate in diisopropylbenzene is not an effective extractant for divalent tetrahedral o xoanions. The presence of 1.5 M NaNO$_2$ in the 1 M NaOH/1.5 M NaNO$_3$ aqueous phase had a modest effect on $K_d$, lowering it to 96. When the aqueous phase consisted of a simulant of Hanford tank 240-AN-106 nominally containing 1 M NaOH, 1.5 M NaNO$_3$, 0.86 M NaNO$_2$, 0.49 M NaAl(OH)$_4$, 0.39 M Na$_2$CO$_3$, 0.11 M Na$_3$PO$_4$, 0.093 M NaCl, 0.073 M Na$_3$(citrate), 0.031 M Na$_2$SO$_4$, and 0.002 M Ca(NO$_3$)$_2$, the value of $K_d$ was $1.5 \times 10^2$ (a small amount of solid was present when this simulant was prepared, so the concentrations of all reagents are listed as nominal).
Table II. Extraction of TcO$_4^-$ from Aqueous Waste Stream Simulants$^a$

<table>
<thead>
<tr>
<th>aqueous phase</th>
<th>$K_d$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 M HNO$_3$</td>
<td>41$^b$</td>
</tr>
<tr>
<td>1 M HNO$_3$</td>
<td>4.9$^c$</td>
</tr>
<tr>
<td>8 M HNO$_3$</td>
<td>0.40$^b$</td>
</tr>
<tr>
<td>1 M NaOH</td>
<td>$6.2 \times 10^2$</td>
</tr>
<tr>
<td>5 M NaOH</td>
<td>$6.9 \times 10^2$</td>
</tr>
<tr>
<td>1 M NaOH/1.5 M NaNO$_3$</td>
<td>$1.1 \times 10^2$ $^d$</td>
</tr>
<tr>
<td>1 M NaOH/1.5 M NaNO$_3$</td>
<td>59$^b$</td>
</tr>
<tr>
<td>1 M NaOH/1.5 M NaNO$_3$</td>
<td>$2.3 \times 10^2$ $^e$</td>
</tr>
<tr>
<td>1 M NaOH/1.5 M NaNO$_3$</td>
<td>$3.7 \times 10^2$ $^f$</td>
</tr>
<tr>
<td>1 M NaOH/1.5 M NaNO$_3$</td>
<td>20 $^g$</td>
</tr>
<tr>
<td>1 M NaOH/1.5 M NaNO$_3$</td>
<td>4.0$^h$</td>
</tr>
<tr>
<td>1 M NaOH/1.5 M NaNO$_3$</td>
<td>$&lt; 1 \times 10^{-3}$ $^c$</td>
</tr>
<tr>
<td>1 M NaOH/1.5 M NaNO$_3$/0.14 M K$_2$CrO$_4$</td>
<td>1.0 $\times 10^2$</td>
</tr>
<tr>
<td>1 M NaOH/1.5 M NaNO$_2$</td>
<td>2.4 $\times 10^2$</td>
</tr>
<tr>
<td>1 M NaOH/1.5 M NaNO$_3$/1.5 M NaNO$_2$</td>
<td>96</td>
</tr>
<tr>
<td>DSS Simulant ([NaOH] = 0.783 M)</td>
<td>1.4 $\times 10^2$</td>
</tr>
<tr>
<td>DSS Simulant ([NaOH] = 1.0 M)</td>
<td>1.5 $\times 10^2$</td>
</tr>
</tbody>
</table>

$^a$ The organic phase was diisopropylbenzene containing 0.2 M Aliquat-336® nitrate unless otherwise noted. $^b$ The organic phase was 7.0% w/w 1-octanol in diisopropylbenzene containing 0.2 M Aliquat-336® nitrate. $^c$ The organic phase was 7.0% w/w 1-octanol in diisopropylbenzene containing ~0.1M DDP+Cl- (DDP+ = 3,5-didodecylpyridinium cation). $^d$ To within experimental error, the same value ($K_d = 1.1 \times 10^2$) was obtained whether the contact (shake) time was 2 min., 5 min., or 24 hours. $^e$ The organic phase was 2,6-dimethyl-4-heptanone (diisobutylketone) containing 0.1 M Aliquat-336® nitrate. $^f$ The organic phase was 2,6-dimethyl-4-heptanone containing 0.2 M Aliquat-336® nitrate. $^g$ The organic phase was neat 2,6-dimethyl-4-heptanone. $^h$ The organic phase was 2-ethyl-1-hexanol containing 0.1 M Aliquat-336® nitrate.
SECTION VII — POSSIBLE ALTERNATE SOLVENTS

After searching the literature and many chemical catalogs, we decided to focus our attention on the following solvents for use as diluents with Aliquat-336 nitrate and other alternative anion extractants. Volatility, flash point, and low solubility in water were of primary concern. Most, but not all, of these solvents were investigated in the third phase of this project.

Table III. Properties of Alternate Organic Solvents

<table>
<thead>
<tr>
<th>mol. formula</th>
<th>b.p. (°C)</th>
<th>F.p. (°C)a</th>
<th>density (g cm⁻³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C₈H₁₈O</td>
<td>183-186</td>
<td>77</td>
<td>0.833</td>
</tr>
<tr>
<td>C₉H₁₈O</td>
<td>169</td>
<td>44</td>
<td>0.808</td>
</tr>
<tr>
<td>C₉H₁₈O</td>
<td>192b</td>
<td>64</td>
<td>0.832</td>
</tr>
<tr>
<td>C₉H₁₈O</td>
<td>187-188</td>
<td>67</td>
<td>0.821</td>
</tr>
<tr>
<td>C₉H₁₈O</td>
<td>186-187</td>
<td>60</td>
<td>0.826</td>
</tr>
<tr>
<td>C₁₀H₁₈O</td>
<td>—c</td>
<td>73</td>
<td>0.881</td>
</tr>
<tr>
<td>C₁₂H₂₆</td>
<td>216</td>
<td>71</td>
<td>0.750</td>
</tr>
<tr>
<td>C₄H₆O₃</td>
<td>240</td>
<td>132</td>
<td>1.189</td>
</tr>
</tbody>
</table>

a Flash point. b At 743 Torr. c The boiling point of this compound is not available.
SECTION VIII — FURTHER STUDIES ON THE EXTRACTION OF ReO$_4^-$

During phase three of this project, we continued to study the extraction of ReO$_4^-$ from nitric acid and from alkaline "waste stream simulants."

The following experimental procedure was used. Twenty mL of aqueous perrhenate solution (1.0, 5.0, or 10.0 mM KReO$_4$, depending on the preliminary $K_d$ value determined in screening experiments) was mixed with 20 mL of a 0.2 M Aliquat-336$^\circledR$ nitrate (methyltricaprylammonium nitrate) solution in diisopropylbenzene (pure 1,3 isomer or technical grade, which contains 96% of the 1,3 isomer) and shaken for 20 min. at 25°C. The phases were separated using separatory funnels (~10 min.) and the aqueous raffinate was collected in either glass or polyethylene vials for analysis on the ICP-AES (Perkin Elmer P400). The distribution ratio ($K_d$) is defined as the concentration of ReO$_4^-$ in the organic phase(s) (the extract) divided by the concentration of ReO$_4^-$ remaining in the aqueous phase (the raffinate). Since we have directly determined only the latter concentration, $K_d$ values were calculated as follows ([ReO$_4^-$]$_i$ is the initial concentration of perrhenate in the aqueous layer and [ReO$_4^-$]$_f$ is the final concentration of perrhenate remaining in the aqueous layer (the raffinate) after the extraction is complete):

$$K_d = \frac{([\text{ReO}_4^-]_f - [\text{ReO}_4^-]_i)}{[\text{ReO}_4^-]_i}$$

Our results are summarized in Table IV, below. Our results clearly show that the aliphatic ketones 2-nonanone (flash point $^\circ$C) and 3-nonanone (flash point $^\circ$C) are superior to diisopropylbenzene as diluents. On the other hand, 2-ethyl-1-hexanol is clearly inferior to DIPB. No third phase was observed when the oxygenated solvents were used to extract ReO$_4^-$ from 1 M HNO$_3$. 

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Table IV. Extraction of ReO$_4^-$ from Aqueous Waste Stream Simulants$^a$

<table>
<thead>
<tr>
<th>aqueous phase</th>
<th>organic solvent</th>
<th>anion extractant</th>
<th>$K_d$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 M HNO$_3$</td>
<td>DIPB</td>
<td>0.2 M Aliquat-336$^+$NO$_3^-$</td>
<td>49$^b$</td>
</tr>
<tr>
<td>1 M HNO$_3$</td>
<td>DIPB</td>
<td>0.2 M Aliquat-336$^+$NO$_3^-$</td>
<td>28$^c$</td>
</tr>
<tr>
<td>1 M HNO$_3$</td>
<td>2-NON</td>
<td>0.2 M Aliquat-336$^+$NO$_3^-$</td>
<td>56</td>
</tr>
<tr>
<td>1 M HNO$_3$</td>
<td>3-NON</td>
<td>0.2 M Aliquat-336$^+$NO$_3^-$</td>
<td>52</td>
</tr>
<tr>
<td>1 M HNO$_3$</td>
<td>EH</td>
<td>0.2 M Aliquat-336$^+$NO$_3^-$</td>
<td>5.5</td>
</tr>
<tr>
<td>1 M NaOH/1.5 M NaNO$_3$</td>
<td>DIPB</td>
<td>0.2 M Aliquat-336$^+$NO$_3^-$</td>
<td>87</td>
</tr>
<tr>
<td>1 M NaOH/1.5 M NaNO$_3$</td>
<td>2-NON</td>
<td>0.2 M Aliquat-336$^+$NO$_3^-$</td>
<td>$1.6 \times 10^2$</td>
</tr>
<tr>
<td>1 M NaOH/1.5 M NaNO$_3$</td>
<td>3-NON</td>
<td>0.2 M Aliquat-336$^+$NO$_3^-$</td>
<td>$1.8 \times 10^2$</td>
</tr>
<tr>
<td>1 M NaOH/1.5 M NaNO$_3$</td>
<td>EH</td>
<td>0.2 M Aliquat-336$^+$NO$_3^-$</td>
<td>5.1</td>
</tr>
</tbody>
</table>

$^a$ Abbreviations: DIPB = diisopropylbenzene; 2-NON = 2-nonanone; 3-NON = 3-nonanone; TMCH = 3,3,5,5-tetramethylcyclohexanone; DMH = 2,6-dimethyl-4-heptanone; EH = 2-ethyl-1-hexanol; Aliquat-336$^+$ = methyltricaprylammonium cation; DDP$^+$ = 3,5-didodecylpyridinium cation; MDDP$^+$ = 1-methyl-3,5-didodecylpyridinium cation. $^b$ A third layer formed in this experiment. $^c$ 7.0% w/w 1-octanol was added to the organic phase to avoid third layer formation.
SECTION IX — FURTHER STUDIES ON THE EXTRACTION OF TcO₄⁻

During this project, Professor Strauss and Dr. Van Seggen spent two-months in the CST-12 group at LANL (June and July, 1994). During that time, we studied the extraction of TcO₄⁻ from a variety of aqueous "waste stream simulants."

The following experimental procedure was used. A sample of either 2.5 or 3.0 mL of aqueous pertechnetate solution (1.5 x 10⁻⁵ M ⁹⁹TcO₄⁻, ~10⁻⁸ M ⁹⁵mTcO₄) was mixed in a thin glass tube with an equal volume of an organic phase containing 0.1 M or 0.2 M extractant and shaken for at least 2 min. at 20°C. The phases were separated by centrifugation (5 min. at 5,000 rpm) and either 1.0 or 1.5 mL of each phase was transferred to a thin plastic tube. The tubes were placed in a gamma ray counting instrument with a NaI(Tl) scintillation detection system (Packard Auto-Gamma® 5530). The number of counts-per-minute (CPM) for each sample and for several blanks (background, BKG) were recorded.

Technetium-95m (I = +1/2) decays with a half-life of 61 days by isomeric transition (4%), positron emission (0.4%) and electron capture with gamma emission (>95%).² Seventy percent of all decay events produce a gamma photon of energy 0.2042 MeV.² These are the photons that are counted (the lower and upper limits of photon energies counted by the instrument were set as 0.165 and 0.245 MeV, respectively).

The distribution ratio (Kd) is defined as the concentration of TcO₄⁻ in the organic phase (the extract) divided by the concentration of TcO₄⁻ remaining in the aqueous phase (the raffinate). Kd values were calculated as follows (the subscripts o and a refer to organic and aqueous phases, respectively):

\[ \text{Kd} = \frac{(\text{CPM}_o - \text{BKG})}{(\text{CPM}_a - \text{BKG})} \]

Our results are summarized in Table V, below. Even allowing for differences in anion extractant concentration, 1-methyl-3,5-didodecylpyridinium iodide is not a more effective extractant than Aliquat-336 nitrate, in either acidic or alkaline waste stream simulants, when the common solvent diisopropylbenzene (DIPB) was used. The search for alternative extractants must continue.

Several ketone solvents gave significantly higher Kd values than DIPB when Aliquat-336 nitrate was used as the extractant. For example, when the aqueous phase was 1 M NaOH and 1.5 M NaNO₃, 3-nonanone containing 0.2 M Aliquat-336 nitrate gave a Kd of 410 while DIPB containing 0.2 M Aliquat-336 nitrate gave a Kd of 110. Of the alternate solvents studied, only 2,6-dimethyl-4-heptanone (diisobutylketone) extracted TcO₄⁻ to any extent on its own (i.e., without an anion extractant like Aliquat-336 nitrate added).
Table V. Extraction of TcO$_4^-$ from Aqueous Waste Stream Simulants$^a$

<table>
<thead>
<tr>
<th>aqueous phase</th>
<th>organic solvent</th>
<th>anion extractant</th>
<th>$K_d$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 M HNO$_3$</td>
<td>DIPB</td>
<td>-0.1 M MDDP$^+$I$^-$</td>
<td>3.6$^b$</td>
</tr>
<tr>
<td>1 M HNO$_3$</td>
<td>DIPB</td>
<td>-0.1 M DDP$^+$Cl$^-$</td>
<td>4.9$^b$</td>
</tr>
<tr>
<td>1 M HNO$_3$</td>
<td>DIPB</td>
<td>0.2 M Aliquat-336$^+$NO$_3^-$</td>
<td>41$^b$</td>
</tr>
<tr>
<td>1 M HNO$_3$</td>
<td>2-NON</td>
<td>0.2 M Aliquat-336$^+$NO$_3^-$</td>
<td>1.4 x 10$^2$</td>
</tr>
<tr>
<td>1 M HNO$_3$</td>
<td>2-NON</td>
<td>0.1 M MDDP$^+$I$^-$</td>
<td>43</td>
</tr>
<tr>
<td>1 M HNO$_3$</td>
<td>3-NON</td>
<td>0.2 M Aliquat-336$^+$NO$_3^-$</td>
<td>1.4 x 10$^2$</td>
</tr>
<tr>
<td>1 M HNO$_3$</td>
<td>TMCH</td>
<td>0.2 M Aliquat-336$^+$NO$_3^-$</td>
<td>2.1 x 10$^2$</td>
</tr>
<tr>
<td>1 M HNO$_3$</td>
<td>DMH</td>
<td>0.2 M Aliquat-336$^+$NO$_3^-$</td>
<td>3.7 x 10$^2$</td>
</tr>
<tr>
<td>1 M NaOH/1.5 M NaNO$_3$</td>
<td>2-NON</td>
<td>0.1 M MDDP$^+$I$^-$</td>
<td>63</td>
</tr>
<tr>
<td>1 M NaOH/1.5 M NaNO$_3$</td>
<td>DIPB</td>
<td>-0.1 M MDDP$^+$I$^-$</td>
<td>6.8</td>
</tr>
<tr>
<td>1 M NaOH/1.5 M NaNO$_3$</td>
<td>DIPB</td>
<td>-0.1 M DDP$^+$Cl$^-$</td>
<td>&lt; 1 x 10$^{-3}$</td>
</tr>
<tr>
<td>1 M NaOH/1.5 M NaNO$_3$</td>
<td>DIPB</td>
<td>0.2 M Aliquat-336$^+$NO$_3^-$</td>
<td>1.1 x 10$^2$</td>
</tr>
<tr>
<td>1 M NaOH/1.5 M NaNO$_3$</td>
<td>2-NON</td>
<td>0.2 M Aliquat-336$^+$NO$_3^-$</td>
<td>3.4 x 10$^2$</td>
</tr>
<tr>
<td>1 M NaOH/1.5 M NaNO$_3$</td>
<td>3-NON</td>
<td>0.2 M Aliquat-336$^+$NO$_3^-$</td>
<td>4.1 x 10$^2$</td>
</tr>
<tr>
<td>1 M NaOH/1.5 M NaNO$_3$</td>
<td>TMCH</td>
<td>0.2 M Aliquat-336$^+$NO$_3^-$</td>
<td>5.7 x 10$^2$</td>
</tr>
<tr>
<td>1 M NaOH/1.5 M NaNO$_3$</td>
<td>EH</td>
<td>0.1 M Aliquat-336$^+$NO$_3^-$</td>
<td>4.0</td>
</tr>
<tr>
<td>1 M NaOH/1.5 M NaNO$_3$</td>
<td>2-NON</td>
<td>none (neat solvent)</td>
<td>1.9 x 10$^{-2}$</td>
</tr>
<tr>
<td>1 M NaOH/1.5 M NaNO$_3$</td>
<td>3-NON</td>
<td>none (neat solvent)</td>
<td>4.4 x 10$^{-3}$</td>
</tr>
<tr>
<td>1 M NaOH/1.5 M NaNO$_3$</td>
<td>TMCH</td>
<td>none (neat solvent)</td>
<td>9.3 x 10$^{-2}$</td>
</tr>
<tr>
<td>1 M NaOH/1.5 M NaNO$_3$</td>
<td>DMH</td>
<td>none (neat solvent)</td>
<td>20</td>
</tr>
</tbody>
</table>

$^a$ Abbreviations: DIPB = diisopropylbenzene; 2-NON = 2-nonanone; 3-NON = 3-nonanone; TMCH = 3,3,5,5-tetramethylcyclohexanone; DMH = 2,6-dimethyl-4-heptanone; EH = 2-ethyl-1-hexanol; Aliquat-336$^+$ = methyltricaprylammonium cation; DDP$^+$ = 3,5-didodecylpyridinium cation; MDDP$^+$ = 1-methyl-3,5-didodecylpyridinium cation. $^b$ 7.0% w/w 1-octanol was added to the organic phase to avoid third layer formation.
SECTION III — COMPARISON OF TcO₄⁻ AND ReO₄⁻ EXTRACTIONS

Some of the data from Tables I, II, IV, and V have been combined in Table VI, below. These are direct comparisons of $K_d$ values for TcO₄⁻ and ReO₄⁻ extractions under similar or identical conditions. The data conclusively demonstrate that perrhenate is a suitable nonradioactive surrogate for pertechnetate as far as solvent extraction technology is concerned.

Table VI. Comparison of TcO₄⁻ and ReO₄⁻ Extractions from Aqueous Waste Stream Simulants

<table>
<thead>
<tr>
<th>aqueous phase</th>
<th>organic solvent</th>
<th>anion extractant</th>
<th>$K_d$ (TcO₄⁻)</th>
<th>$K_d$ (ReO₄⁻)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 M HNO₃</td>
<td>DIPB</td>
<td>0.2 M Aliquat-336*NO₃⁻</td>
<td>41ᵇ</td>
<td>28ᵇ</td>
</tr>
<tr>
<td>1 M HNO₃</td>
<td>2-NON</td>
<td>0.2 M Aliquat-336*NO₃⁻</td>
<td>1.4 x 10²</td>
<td>56</td>
</tr>
<tr>
<td>1 M HNO₃</td>
<td>3-NON</td>
<td>0.2 M Aliquat-336*NO₃⁻</td>
<td>1.4 x 10²</td>
<td>52</td>
</tr>
<tr>
<td>8 M HNO₃</td>
<td>DIPB</td>
<td>0.2 M Aliquat-336*NO₃⁻</td>
<td>0.4₀ᵇ</td>
<td>0.6₁ᵇ,ᶜ</td>
</tr>
<tr>
<td>1 M NaOH</td>
<td>DIPB</td>
<td>0.2 M Aliquat-336*NO₃⁻</td>
<td>5.0 x 10²</td>
<td>3.0 x 10³</td>
</tr>
<tr>
<td>5 M NaOH</td>
<td>DIPB</td>
<td>0.2 M Aliquat-336*NO₃⁻</td>
<td>6.9 x 10²</td>
<td>6.1 x 10³</td>
</tr>
<tr>
<td>1 M NaOH/1.5 M NaNO₃</td>
<td>DIPB</td>
<td>0.2 M Aliquat-336*NO₃⁻</td>
<td>1.1 x 10²</td>
<td>87</td>
</tr>
<tr>
<td>1 M NaOH/1.5 M NaNO₃</td>
<td>DIPB</td>
<td>0.2 M Aliquat-336*NO₃⁻</td>
<td>59ᵇ</td>
<td>29ᵇ</td>
</tr>
<tr>
<td>1 M NaOH/1.5 M NaNO₃</td>
<td>2-NON</td>
<td>0.2 M Aliquat-336*NO₃⁻</td>
<td>3.4 x 10²</td>
<td>1.6 x 10²</td>
</tr>
<tr>
<td>1 M NaOH/1.5 M NaNO₃</td>
<td>3-NON</td>
<td>0.2 M Aliquat-336*NO₃⁻</td>
<td>4.1 x 10²</td>
<td>1.8 x 10²</td>
</tr>
</tbody>
</table>

ᵃ Abbreviations: DIPB = diisopropylbenzene; 2-NON = 2-nonanone; 3-NON = 3-nonanone; Aliquat-336⁺ = methyltricaprylammonium cation. ᵇ 7.0% w/w 1-octanol was added to the organic phase to avoid third layer formation. ᵇ The nitric acid concentration for this experiment was 7.6 M instead of 8 M.
SECTION XI — POSSIBLE ALTERNATE EXTRACTANTS

We have started to examine extractants other than Aliquat-336 nitrate. This line of experimentation is driven by the desire to discover an extractant more effective than, and less prone to radiolysis than, Aliquat-336 nitrate. The extractant 1-methyl-3,5-didodecylpyridinium iodide was obtained from Professor R. A. Bartsch at Texas Tech University (the cation is shown below). We have converted this extractant to the nitrate salt. ones we have obtained or prepare are shown in Figure 1, below. In addition, we have also prepared 1-methyl-4-(1-butylpentyl)pyridinium nitrate. Other N-methylpyridinium nitrates, shown below as their cations, have been prepared.

Unfortunately, all of the compounds except for 1-methyl-3,5-didodecylpyridinium iodide and 1-methyl-3,5-didodecylpyridinium nitrate are too soluble in water to function as anion extractants in this work. Only these two pyridinium salts, and their 1-trimethylsilylmethyl analogs, will be used for future work.
REFERENCES


Notes: 14333-24-5 is ReO$_4^-$
14333-20-1 is TcO$_4^-$

=> s 14333-24-5 and extract?

388 14333-24-5
85108 EXTRACT?

L2 47 14333-24-5 AND EXTRACT?

L2 ANSWER 1 OF 47
AN CA118(18):176907v
TI Correlation parameters for predicting anion-exchange ***extraction*** constants for 287 containing 236 different anions on an ES computer with the program QPACG2.
AU Mezhov, E. A.; Reymarov, G. A.; Khananishvili, N. L.; Schmidt, V. S.
LO Russia
SO Radiokhimiya, 34(1), 9-50
SC 68-2 (Phase Equilibriums, Chemical Equilibriums, and Solutions)
SX 20, 48, 54
DT J
CO RADKAU
IS 0033-8311
PY 1992
LA Russ

L2 ANSWER 2 OF 47
AN CA118(2):12320x
TI Studies on the ***extraction*** of perrhenate by use of crown ethers.
AU Jewad, S. K.; Al-Murab, S. R.; Jalhoom, M. G.
CS Coll. Educ., Univ. Baghdad
LO Baghdad, Iraq
SC 68-2 (Phase Equilibriums, Chemical Equilibriums, and Solutions)
SX 69
DT J
CO PMETEQ
PY 1992
LA Eng

L2 ANSWER 3 OF 47
AN CA116(20):206729s
TI ***Extraction*** and adsorption of chlorocomplexes, perrhenate (ReO$_4^-$), and tetrafluoroborate (BF$_4^-$) with crown ethers and a crown ether polymer.
AU Onishi, Hiroshi; Koshima, Hideko
CS Dep. Chem., Univ. Tsukuba
LO Tsukuba 305, Japan

L2 ANSWER 4 OF 47
AN CA115(22):246930m
TI ***Extraction*** spectrophotometric study of the system of tetrazolium violet-perrhenate-water-chloroform. Determination of rhenium in copper ore.
AU Simeonova, Zh.; Aleksandrov, A.; Stoimenov, N.
LO Bulgaria
SO Nauchni Tr. - Plovdivskii Univ., 27(5, Khim.), 39-52
SC 79-6 (Inorganic Analytical Chemistry)
SX 68
DT J
CO NTUPB6
IS 0369-6227
PY 1989
LA Bulg

L2 ANSWER 5 OF 47
AN CA115(16):131212z
TI Anion ***extraction*** in the water-inorganic salt-polar organic solvent system.
AU Shevchuk, I. A.; Makhno, A. Ya.
CS Donetsk. Gos. Univ.
LO Donetsk, USSR
SC 79-1 (Inorganic Analytical Chemistry)
SX 68, 80
DT J
CO UKZHUAU
IS 0041-6045
PY 1989
LA Russ
Effect of solution ionic strength and temperature on the extraction of perrhenate associates of tris(1,10-phenanthroline)iron(II)

Karmanova, E. G.; Belousov, E. A.
LO Leningrad, USSR
SO Zh. Neorg. Khim., 29(7), 1879-81
SC 68-2 (Phase Equilibriums, Chemical Equilibriums, and Solutions)

Quantitative description using linear relationships of free energies for a new set of anion-exchange extraction constants for a series of single-charged anions

Shmidt, V. S.; Rybakov, K. A.; Rubisov, V. N.
LO USSR
SO Zh. Neorg. Khim., 27(6), 1519-22
SC 66-2 (Phase Equilibriums, Chemical Equilibriums, and Solutions)
SX 66, 69
DT J

Use of liquid extraction membranes for selective recovery of metals in electrochemical processes

Golubev, V. N.; Purins, B.
LO Riga, USSR
SC 66-4 (Surface Chemistry and Colloids)
SX 68, 80
DT J

Extraction chromatography of common anions in liquid-liquid anion exchange systems. Part. III. Monobasic aliphatic organic acids and their sodium salts as eluants

Przeszlakowski, S.; Kocjan, R.
LO Lublin 20-081, Pol.
SO Chromatographia, 12(9), 587-94
SC 79

Extraction of rhenium(VI) by petroleum sulfoxides

Numanov, I. U.; Akhmadieva, R. G.; Yusupova, N. A.
LO Dushanbe, USSR
SO Dokl. Akad. Nauk Tadzh. SSR, 23(10), 582-5
SC 68-1 (Phase Equilibriums, Chemical Equilibriums, and Solutions)

Extraction of elements as oxygen anions from alkaline solutions. IV. Extraction of rhenium(VII) with tributyl phosphate

Dakar, G. M.; Iofa, B. Z.; Nesmeyanov, A. N.
LO USSR
SO Radiokhimiya, 21(3), 409-12
SC 68-1 (Phase Equilibriums, Chemical Equilibriums, and Solutions)

Extraction of rhenium from sulfuric acid solutions using neutral extractants

Adamova, A. Zh.; Ponomareva, E. I.
Effect of a microcomponent on electrochemical and extraction properties of a liquid membrane in a macrocomponent solution

AU Golubev, V. N.; Purins, B.; Filatova, T. A.; Nikolaev, N. I.; Chuvileva, G. G.

LO Riga, USSR
SC 66-4 (Surface Chemistry and Colloids)
DT C
CO 39BPAK
PY 1977
LA Russ

Effect of current pulse imposition on electrochemical transfer of ions through liquid extraction membranes

AU Golubev, V. N.; Purins, B.; Filatova, T. A.

LO Riga, USSR
SC 68-1 (Phase Equilibriums, Chemical Equilibriums, and Solutions)
DT C
CO 35THAO
PY 1976
LA Russ

Study of the principles of ion transfer through liquid extraction membranes. II. Selectivity of ion transfer

AU Golubev, V. N.; Filatova, T. A.

LO Riga, USSR
SC 66-2 (Surface Chemistry and Colloids)
DT J
CO LZAKAM
IS 0002-3248
PY 1978
LA Russ

Effect of a microcomponent on electrochemical and extraction properties of a liquid membrane in a macrocomponent solution

AU Golubev, V. N.; Purins, B.; Filatova, T. A.; Nikolaev, N. I.; Chuvileva, G. G.

LO Riga, USSR
SC 66-4 (Surface Chemistry and Colloids)
DT C
CO 39BPAK
PY 1977
LA Russ

Study of the principles of ion transfer through liquid extraction membranes. I. Selectivity of ion transfer

AU Golubev, V. N.; Purins, B.; Filatova, T. A.

LO Riga, USSR
SC 66-2 (Surface Chemistry and Colloids)
DT J
CO LZAKAM
IS 0002-3248
PY 1978
LA Russ

Effect of current pulse imposition on electrochemical transfer of ions through liquid extraction membranes

AU Golubev, V. N.; Purins, B.

LO Riga, USSR
SC 66-4 (Surface Chemistry and Colloids)
DT J
CO LZAKAM
PY 1977
LA Russ

Study of the characteristics of ion transfer through liquid extraction membranes. I. Diffusion transfer of ions

AU Golubev, V. N.; Purins, B.; Filatova, T. A.

LO Riga, USSR
SC 65-1 (General Physical Chemistry)
DT J
CO LZAKAM PY 1977 LA Russ
L2  ANSWER 28 OF 47
AN  CA86(16):111664q
TI  Features of the ***extraction*** of the perrhenate ion with
  basic acridine orange dye
AU  Tarayan, V. M.; Mirzoyan, F. V.;
    Sarkisyan, Zh. V.
CS  Erevan. Gos. Univ.
LO  Yerevan, USSR
SO  Dokl. Akad. Nauk Arm. SSR, 63(1), 36-41
SC  68-1 (Phase Equilibriums, Chemical
    Equilibriums, and Solutions)
SX  79
DT  J
CO  DANAAB
PY  1976
LA  Russ

L2  ANSWER 29 OF 47
AN  CA85(18):136816h
TI  Study of liquid-liquid ***extraction*** of perrhenate with
cyclohexanone in different media
AU  Jordanov, N.; Pavlova, M.; Bojkova, D.
LO  Sofia, Bulg.
SO  Talanta, 22(6), 463-5
SC  79-6 (Inorganic Analytical Chemistry)
DT  J
CO  TLNTA2
PY  1976
LA  Russ

L2  ANSWER 30 OF 47
AN  CA85(18):112395y
TI  On the characteristics of ***extraction*** of the perrhenate ion with
  the basic dye victoria blue 4R
AU  Tarayan, V. M.; Mirzoyan, F. V.;
    Sarkisyan, Zh. V.
CS  Erevan. Gos. Univ.
LO  Yerevan, USSR
SC  68-1 (Phase Equilibriums, Chemical
    Equilibriums, and Solutions)
DT  J
CO  AYKZAN
PY  1974
LA  Russ

L2  ANSWER 31 OF 47
AN  CA83(22):184233w
TI  ***Extraction*** of astraphloxin salts
AU  Borisova, I. A.; Sergievskii, V. V.
LO  USSR
SC  68-1 (Phase Equilibriums, Chemical
    Equilibriums, and Solutions)
SX  79
DT  J
CO  TKTKE
PY  1974
LA  Russ

L2  ANSWER 32 OF 47
AN  CA83(18):153285k
TI  Mechanism of solvent ***extraction*** of perrhenate ions by
cyclohexanone
AU  Jordanov, N.; Pavlova, M.; Bojkova, D.
LO  Sofia, Bulg.
SC  68-1 (Phase Equilibriums, Chemical
    Equilibriums, and Solutions)
DT  C
CO  30XIAE
PY  1974
LA  Eng

L2  ANSWER 33 OF 47
AN  CA83(14):121456a
TI  ***Extraction*** of perrhenate ion by the basic dye methyl green
AU  Tarayan, V. M.; Mirzoyan, F. V.;
    Sarkissyan, Zh. V.
CS  Erevan. Gos. Univ.
LO  Yerevan, USSR
SO  Arm. Khim. Zh., 27(10), 825-31
SC  68-1 (Phase Equilibriums, Chemical
    Equilibriums, and Solutions)
SX  79
DT  J
CO  AYKZAN
PY  1974
LA  Russ

L2  ANSWER 34 OF 47
AN  CA83(10):87311n
TI  Conductivity of model ***extraction*** membranes in the presence
  of thiooxine and several of its derivatives
AU  Golubev, V. N.; Purins, B.
LO  Riga, USSR
    (1), 40-3
SC  72-12 (Electrochemistry)
SX  76
DT  J
CO  LZAKAM
PY  1975
LA  Russ
L2 ANSWER 35 OF 47
AN CA81(26):177772b
TI Electrochemical transfer of some anions through liquid 
***extraction*** membrane (triocetylamine-amyl alcohol)
AU Golubev, V. N.; Purins, B.; Filatova, T. A.
LO Riga, USSR
SC 68-4 (Phase Equilibriums, Chemical Equilibriums, and Solutions)
SX 66
DT J
CO LZAKAM
PY 1974
LA Russ

L2 ANSWER 36 OF 47
AN CA81(26):176557b
TI Electrochemical transfer of perrhenate ions through the 
***extraction*** membranes
AU Golubev, V. N.; Purins, B.; Filatova, T. A.
LO Riga, USSR
SC 68-2 (Surface Chemistry and Colloids)
DT J
CO LZAKAM
PY 1974
LA Russ

L2 ANSWER 37 OF 47
AN CA81(26):176554v
TI Ionic selectivity of model ***extraction*** membranes
AU Golubev, V. N.; Purins, B.
LO Riga, USSR
Elektrokhim. Org. Soedin., 8th, Meeting
Date 1973, 121. Edited by: 
Foktistov, L. G. "Zinatne": Riga, USSR.
SC 66-2 (Surface Chemistry and Colloids)
DT C
CO 28TSAX
PY 1973
LA Russ

L2 ANSWER 38 OF 47
AN CA81(26):159863c
TI Indirect evaluation of the selectivity of liquid 
***extraction*** membranes
AU Golubev, V. N.; Purins, B.
LO Riga, USSR
SC 68-2 (Phase Equilibriums, Chemical Equilibriums, and Solutions)
SX 66
DT J
CO LZAKAM
PY 1974
LA Russ

L2 ANSWER 39 OF 47
AN CA81(26):30248b
TI Solvent ***extraction*** from molten salts. X. 
***Extraction*** of perrhenate by alkylammonium salts
AU David-Auslaender, J.; Zangen, M.; Kertes, A. S.
LO Yavne, Israel
SC 68-1 (Phase Equilibriums, Chemical Equilibriums, and Solutions)
DT J
CO GSKFAL
PY 1972
LA Bulg

L2 ANSWER 40 OF 47
AN CA80(4):20030
TI Possibility of ***extraction*** of rhenium(VII) with some 
carbonyl group-containing organic compounds
AU Kálecheva, V.; Angelova, V.; Doicheva, R.; Simov, D.
CS Sofia Univ.
LO Sofia, Bulg.
SC 68-1 (Phase Equilibriums, Chemical Equilibriums, and Solutions)
DT J
CO GSKFAL
PY 1972
LA Bulg

L2 ANSWER 41 OF 47
AN CA77(10):66698e
TI ***Extraction*** of some anions from molten lithium 
nitrate-potassium nitrate by tetraoctylphosphonium nitrate in 
polyphenyl or 1-nitronaphthalene solvent
AU Tan, Zillo C. H.; Irvine, J. W., Jr.
LO Cambridge, Mass., USA
SO Inorg. Chem., 11(7), 1701-7
SC 68-1 (Phase Equilibriums, Chemical Equilibriums, and Solutions)
DT J
CO NOCAJ
PY 1972
LA Eng

Contract 669HH0013-9Z page 38 Final Report
L2 ANSWER 42 OF 47
AN CA76(18):107600s
TI Analytical properties of the indicator Nile Blue. II.
***Extraction*** -photometric
determination of some anions with the
blue form of Nile Blue
AU Savic, M.; Savic, J.
LO Sarajevo, Yugoslavia
SO Glas. Hem. Tehnol. Bosne Hercegovine,
No. 17, 5-11
SC 79 (Inorganic Analytical Chemistry)
DT J
CO GHTBAB
PY 1969
LA Fr

L2 ANSWER 43 OF 47
AN CA75(4):26041n
TI Equilibriums in perrhenate ion-bis-(4-
methy1benzylaminophenyl)antipy
rylcarbinol-organic solvent **extraction**
systems
AU Busev, A. I.; Dzintarnieks, M.; Rudzitis,
G.; Ogareva, M. B.
CS M. V. Lomonosov Moscow State Univ.
LO Moscow, USSR
SC 68 (Phase Equilibriums, Chemical
Equilibriums, and Solutions)
DT J
CO ZSTKAI
PY 1971
LA Russ

L2 ANSWER 44 OF 47
AN CA69(18):70572m
TI Organic oxides as ***extractants*** for
metal anions
AU Krasovec, F.; Klofutar, C.
CS Inst. "Jozef Stefan"
LO Ljubljana, Yugoslavia
Goteborg, Volume Date 1966
509-16
SC 68 (Phase Equilibriums, Chemical
Equilibriums, and Solutions)
DT J
CO 19CVAL
PY 1967
LA Eng

L2 ANSWER 45 OF 47
AN CA69(18):70548h
TI Solvent ***extraction*** of some anions
from molten NH4NO3.2H2O
with tetraheptylammonium nitrate
AU Nikolic, R. M.; Gal, I. J.
LO Belgrade, Yugoslavia
SC 68 (Phase Equilibriums, Chemical
Equilibriums, and Solutions)
DT J
CO MIACAQ
PY 1973
LA Ger

L2 ANSWER 46 OF 47
AN CA67(12):57672h
TI Ion exchange ***extraction*** of rhenium
from alkaline solution
AU Lebedev, K. B.; Ageev, A. V.
17(2), 5-11
SC 68 (Phase Equilibriums, Chemical
Equilibriums, and Solutions)
DT J
CO JINCAO
PY 1968
LA Eng

L2 ANSWER 47 OF 47
AN CA78(12):79308y
TI Morpholinium morpholine-N-
dithiocarbamate as a reagent in
***quantitative*** analysis. IX.
***Spectrophotometric***
determination of ***rhenium***
AU Likussar, W.; Beyer, W.
LO Graz, Austria
SO Mikrochim. Acta, (2), 211-17
SC 79-6 (Inorganic Analytical Chemistry)
DT J
CO JINCAO
PY 1968
LA Eng
Spectrophotometric determination of rhenium with thiocyanate and hydroxamic acids

AU Sharma, Indrani; Chakraburty, A. K.
CS Dep. Chem., Jadavpur Univ.
LO Calcutta 700 032, India
SC 79-6 (Inorganic Analytical Chemistry)
DT J
CO IJCADU
IS 0376-4710
PY 1988
LA Eng

Spectrophotometric determination of chloride in platinum-alumina/silica catalysts with mercuric thiocyanate reagent

AU Kosh V.; Garg, V. N.
CS Res. Cent., Indian Petrochem. Corp. Ltd.
LO Baroda 391 346, India
SO Talanta, 34(11), 905-8
SC 79-6 (Inorganic Analytical Chemistry)
DT J
CO TLNTA2
IS 0039-9140
PY 1987
LA Eng

Spectrophotometric determination of chloride in platinum-alumina/silica catalysts with metoclopramide hydrochloride

AU Ramappa, P. G.; Ramachandra, K. S.
CS Dep. Chem.
LO Mysore 570006, India
SO J. Inst. Chem. (India), 59(2), 115
SC 79-6 (Inorganic Analytical Chemistry)
DT J
CO JOICA7
IS 0020-3254
PY 1987
LA Eng

An improved thiocyanate method for the determination of rhenium

AU Yatirajam, V.; Khaira, Sirpal; Kakkar, L. R.
CS Dep. Chem., Kurukshetra Univ.
LO Kurukshetra 132 119, India
SC 79-2 (Inorganic Analytical Chemistry)
DT J
CO IJCADU
IS 0376-4710
PY 1986
LA Eng
TI Determination of rhenium by a thiocyanate method in the absence of an extractant
AU Ermolaev, M. I.; Gukova, Yu. Ya.; Kuznetsova, N. A.
LO USSR
SO Tr. Voronezh. Tekhnol. Inst., No. 18.74-5
SC 79-6 (Inorganic Analytical Chemistry)
DT J
PY 1970
LA Russ

TI Spectrophotometric determination of thiocyanate
AU Neas, Robert E.; Guyon, John C.
CS Univ. of Missouri
LO Columbus, Mo., USA
SO Anal. Chem., 41(11), 1470-3
SC 79 (Inorganic Analytical Chemistry)
DT J
PY 1969
LA Eng

TI Spectrophotometric determination of trace amounts of rhenium
AU Basinska, Maria; Rutkowski, Wladyslaw
CS Inst. Badan Jadrowych
LO Warsaw, Poland
SO Chem. Anal. (Warsaw), 13(4), 799-807
SC 79 (Inorganic Analytical Chemistry)
DT J
CO CANWAJ
PY 1968
LA Pol

TI The thiocyanate method for the photometric determination of rhenium
AU Iordanov, N.; Pavlova, M.
CS Bulgarian Acad. Sci.
LO Sofia, Bulg.
SC 79 (Inorganic Analytical Chemistry)
DT J
CO 19SWA2
PY 1966
LA Eng

TI Analytical studies of rhenium III.
**Spectrophotometric** determination of rhenium with thiocyanate and anion exchange separation of molybdenum and rhenium
AU Kojima, Masuo; Okubo, Teiji
SO Tokyo Kogyo Shikensho Hokoku, 61(9), 372-7
SC 79 (Inorganic Analytical Chemistry)
DT J
CO TKSHAI
PY 1966
LA Japan

=> s rhenium and recovery
14660 RENIUM
97670 RECOVERY
L6 325 RENIUM AND RECOVERY
=> s 16 and 14333-24-5
388 14333-24-5
L7 7 L6 AND 14333-24-5
=> d 17 1-7
**L7 ANSWER 3 OF 7**

**AN** CA102(10):81046u

**TI** Recovery of rhenium salts from aqueous solutions of perrhenates

**AU** Petrovich, V. A.; Tabulina, L. V.; Arzhanov, S. I.

**CS** MRTI

**LO** USSR

**SO** Khim. Khim. Tekhnol. (Minsk), 19, 47-9

**SC** 49-5 (Industrial Inorganic Chemicals)

**SX** 54

**DT** J

**CO** KITEDK

**PY** 1984

**LA** Russ

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**L7 ANSWER 4 OF 7**

**AN** CA99(18):142455v

**TI** Recovery of perrhenate compounds from aqueous solutions

**AU** Zerisch, Siegfried

**CS** VEB Mansfeld-Kombinat "Wilhelm Pieck"; Forschungsinstitut fuer NE-Metalle


**SO** Ger. (East), 16 pp.

**PI** DD 200566 Z 18 May 1983

**AI** DD 81-23273 24 Aug 1981

**IC** C01G047-00

**SC** 49-5 (Industrial Inorganic Chemicals)

**SX** 54

**DT** P

**CO** GEXXAK

**PY** 1983

**LA** Ger

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**L7 ANSWER 5 OF 7**

**AN** CA91(24):201201u

**TI** Redox potential-pH diagram of the rhenium-sulfur-water system

**AU** Kanimov, K. K.; Ogorodnikov, Yu. I.


**LO** Alma-Ata, USSR

**SO** Deposited Doc., VINITI 2913-78, 14 pp. Avail. VINITI

**SC** 72-12 (Electrochemistry)

**SX** 54, 69

**DT** T

**PY** 1978

**LA** Russ

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**L7 ANSWER 6 OF 7**

**AN** CA73(22):113294z

**TI** Use of acidified urea solutions as a desorbent

**AU** Suvorovskaya, N. A.; Shikhova, V. V.; Shmarinova, I. A.; Karavaeva, S. D.

**LO** USSR

**SO** Nauch. Soobshch., Inst. Gorn. Dela, Moscow, 47, 39-41

**PY** 1978

**LA** Russ

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**L7 ANSWER 7 OF 7**

**AN** CA72(22):114073t

**TI** Flotation of anions with the aid of cationic surfactants. II.

**AU** Charewicz, Witold; Niemiec, Jan

**CS** Polytech.

**LO** Wroclaw, Poland

**SO** Nukleonika, 14(6), 607-17

**SC** 54 (Extractive Metallurgy)

**PY** 1969

**LA** Eng

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**L8 ANSWER 1 OF 15**

**AN** CA118(18):178762t

**TI** Electron-transfer behavior of oxorhenium(V), nitridorhenium(V) and rhenium(III) diethyldithiocarbamate complexes

**AU** Holder, Grant N.; Kanning, Mark W.

**CS** Dep. Chem., Appalachian State Univ.

**LO** Boone, NC 28608, USA


**SC** 72-2 (Electrochemistry)

**SX** 66, 78

**DT** T

**PY** 1992

**LA** Eng

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**L8 ANSWER 2 OF 15**

**AN** CA118(16):159836d

**TI** Coordination compounds of pentaaminerhenium(III/II)

**AU** Orth, Stephen D.; Barrera, Joseph; Sabat, Michal; Harman, W. Dean

**CS** Dep. Chem., Univ. Virginia

**LO** Charlottesville, VA 22901, USA


**SC** 78-7 (Inorganic Chemicals and Reactions)

**SX** 68, 75

**DT** T

**PY** 1993

**LA** Eng

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**Final Report**
L8 ANSWER 9 OF 15
AN CA110(18):164966k
TI Synthesis, optical, photophysical, and redox properties of a ligand-bridged heteronuclear (OC)5W(pyz)=Re(CO)4Cl (pyz = pyrazine) complex
AU Zulu, Mthembeni M.; Lees, Alistair J.
LO Binghamton, NY 13901, USA
SO Organometallics, 8(4), 955-60
SC 78-7 (Inorganic Chemicals and Reactions)
SX 72, 73, 74
DT J
CO ORGND7
IS 0276-7333
PY 1989
LA Eng
OS CJACS

L8 ANSWER 10 OF 15
AN CA108(13):112170k
TI Polybipyridine ligands derived from acyclic and macrocyclic polyamines; synthesis and metal-binding studies
AU Lehn, Jean Marie; Ziessel, Raymond
CS Inst. Le Bel, Univ. Louis Pasteur
LO Strasbourg F-67000, Fr.
SC 27-16 (Heterocyclic Compounds (One Hetero Atom))
SX 78
DT J
CO JCCCAT
IS 0022-4936
PY 1987
LA Eng
OS CASREACT 108:112170; CJRSC

L8 ANSWER 11 OF 15
AN CA108(8):65856b
TI Photo- and electrochemical reduction of carbon dioxide
AU Ziessel, Raymond
CS Inst. Le Bel, Univ. Louis Pasteur
LO Strasbourg F-67000, Fr.
SC 27-16 (Heterocyclic Compounds (One Hetero Atom))
SX 74-1 (Radiation Chemistry, Photochemistry, and Photographic and Other Reprographic Processes)
SX 52, 67, 72
DT J
CO NSCSDW
PY 1987
LA Eng

L8 ANSWER 12 OF 15
AN CA93(16):160405j
TI Structures and redox behavior of transition metal complexes formed with cyclic tetrapyrroles - syntheses of monomeric metal complexes for development of polymer materials having red conductivity
AU Murakami, Yukito; Matsuda, Yoshihisa; Yamada, Sunao; Goto, Takashi; Kuramoto, Masahiko
CS Fac. Eng., Kyushu Univ.
LO Fukuoka, Japan
SO Kenkyu Hokoku - Asahi Garasu Kogyo Gijutsu Shokei, 34, 295-312
SC 78-7 (Inorganic Chemicals and Reactions)
SX 72
DT J
CO AGKGAA
IS 0365-2599
PY 1979
LA Japan

L8 ANSWER 13 OF 15
AN CA73(10):51511g
TI ***Rhenium*** oxides. I. ***Rhenium*** trioxide electrode potentials in acid media
AU Poisson, Regis; Chartier, Pierre; Brenet, Jean
LO Strasbourg, Fr.
SC 77 (Electrochemistry)
DT J
CO BSCFAS
PY 1970
LA Fr

L8 ANSWER 14 OF 15
AN CA71(22):106346y
TI Correlation of standard oxidation-reduction potentials with crystal chemical parameters in oxygen compounds of some transition metals
AU Goncharenko, A. S.
LO USSR
SO Zh. Neorg. Khim., 14(8), 2053-5
SC 70 (Crystallization and Crystal Structure)
DT J
CO ZNOKAQ
PY 1969
LA Russ

L8 ANSWER 15 OF 15
AN CA70(4):16589e
TI ***Redox*** ***potentials*** of ***rhenium*** in hydrochloric and sulfuric acid solutions
AU Henze, Guenter; Geyer, Rudolf
LO Merseburg, Ger.
SO Z. Chem., 8(9), 349-50
SC 77 (Electrochemistry)
DT J
CO ZECEAL
PY 1968
LA Ger
=> s 14333-24-5 and redox(w)potentials not l8
  388 14333-24-5
  33790 REDOX
  18448 POTENTIALS
  910 REDOX(W)POTENTIALS
L9  0 14333-24-5 AND
REDOX(W)POTENTIALS NOT L8

=> s 14333-24-5 and redox(w)potential not l8
  388 14333-24-5
  33790 REDOX
  19044 POTENTIAL
  4315 REDOX(W)POTENTIAL
L10 1 14333-24-5 AND
REDOX(W)POTENTIAL NOT L8

=> d 110
L10 ANSWER 1 OF 1
AN CA91(24):201201u
TI "Redox"" potential" -pH
diagram of the
chromium-sulfur-water system
AU Kanimov, K. K.; Ogorodnikov, Yu. I.
LO Alma-Ata, USSR
SO Deposited Doc., VINITI 2913-78, 14 pp.
Avail. VINITI
SC 72-12 (Electrochemistry)
SX 54,69
DT T
PY 1978
LA Russ

=> s technetium and redox(w)potential?
  7649 TECHNETIUM
  33790 REDOX
  203416 POTENTIAL?
  4627 REDOX(W)POTENTIAL?
L11 15 TECHNETIUM AND
REDOX(W)POTENTIAL?

=> s l11 not l8
L12 15 L11 NOT L8

=> d 112 1-15
L12 ANSWER 1 OF 15
AN CA116(14):137806a
TI Chemistry of the redox sensitive elements.
Literature review
AU Suter, Daniel
CS Paul Scherrer Inst.
LO CH-5232, Switz.
SO PSI-Ber., 113, 72 pp.
SC 71-0 (Nuclear Technology)
SX 72
DT T
CO PSIBEY
PY 1991
LA Eng
TI Thermodynamic properties of \(*\)technetium\(*\) (IV) oxides: solubilities and the electrode potential of the \(*\)technetium\(*\)

(VII)/ \(*\)technetium** (IV)-oxide couple

AU Meyer, R. E.; Arnold, W. D.; Case, F. I.; O'Kelley, G. D.

CS Oak Ridge Natl. Lab.

LO Oak Ridge, TN, USA

SO Report, ORNL-6480; Order No. NUREG/CR-5108, 33 pp. Avail. NTIS


SC 72-2 (Electrochemistry)

SX 68, 69, 71

DT T

PY 1988

LA Eng

L12 ANSWER 6 OF 15

TI ***Technetium*** in the hydrosphere and in the geosphere. I. Chemistry of ***technetium*** and iron in natural waters and influence of the ***redox*** on the sorption of ***technetium***

AU Lieser, K. H.; Bauscher, C.


SO Radiochim. Acta, 42(4), 205-13

SC 53-11 (Mineralogical and Geological Chemistry)

SX 61

DT J

CO RAACAP

IS 0033-8230

PY 1987

LA Eng

L12 ANSWER 7 OF 15

TI ***Technetium*** electrochemistry. 3. Spectroelectrochemical studies on the mixed-ligand ***technetium*** (III) complexes trans-[Tc(PR2R)2L]+ where L is a tetradentate Schiff base ligand and PR2R is a monodentate tertiary phosphine ligand

AU Ichimura, Akio; Heineman, William R.; Deutsch, Edward

CS Dep. Chem., Univ. Cincinnati

LO Cincinnati, OH 45221, USA

SO Inorg. Chem., 24(14), 2134-9

SC 72-2 (Electrochemistry)

SX 73, 78

DT J

CO INOCAJ

IS 0020-1669

PY 1985

LA Eng

OS CJACS

L12 ANSWER 8 OF 15

TI A spectroelectrochemical study of the ***technetium*** (IV)/ ***technetium*** (III) couple in bicarbonate solutions

AU Paquette, Jean; Lawrence, Warwick E.


LO Pinawa, MB ROE 1L0, Can.


SC 72-2 (Electrochemistry)

SX 67, 68, 73

DT J

CO CJCHAG

IS 0008-4042

PY 1985

LA Eng

L12 ANSWER 9 OF 15

TI A spectroelectrochemical study of the ***technetium*** (IV)/ ***technetium*** (III) couple in bicarbonate solutions

AU Paquette, Jean; Lawrence, Warwick E.


LO Pinawa, MB ROE 1L0, Can.


SC 72-2 (Electrochemistry)

SX 67, 68, 73

DT J

CO CJCHAG

IS 0008-4042

PY 1985

LA Eng

OS CJACS

L12 ANSWER 10 OF 15

TI The behavior of ***technetium*** -99 in doped-glass/basalt hydrothermal interaction tests

AU Coles, D. G.; Apted, M. J.

CS Pac. Northwest Lab.

LO Richland, WA 99352, USA


SC 71-11 (Nuclear Technology)

SX 53, 57

DT J

CO MRSPDH

IS 0272-9172

PY 1984

LA Eng
**L12 ANSWER 11 OF 15**

**AN** CA100(20):164046d

**TI** ***Technetium*** electrochemistry. 2.

Electrochemical and spectroelectrochemical studies of the bis(tertiary phosphate) (D) complexes trans-[TcD2X2]+ (X = chlorine or bromine)

**AU** Ichimura, Akio; Heineman, William R.; Vanderheyden, Jean Luc; Deutsch, Edward

**CS** Dep. Chem., Univ. Cincinnati

**LO** Cincinnati, OH 45221, USA

**SO** Inorg. Chem., 23(9), 1272-8

**SC** 72-2 (Electrochemistry)

**SX** 8, 73, 78

**DT** J

**CO** INOCAJ

**IS** 0020-1669

**PY** 1984

**LA** Eng

**OS** CJACS

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**L12 ANSWER 12 OF 15**

**AN** CA99(6):46958r

**TI** Synthesis, characterization, and electrochemical properties of tertiary diphosphine complexes of ***technetium***

trans-[Tc(DPPE)2Br2]BF4

**AU** Libson, Karen; Barnett, B. L.; Deutsch, Edward

**CS** Dep. Chem., Univ. Cincinnati

**LO** Cincinnati, OH 45221, USA

**SO** Inorg. Chem., 22(12), 1695-704

**SC** 78-7 (Inorganic Chemicals and Reactions)

**SX** 70

**DT** J

**CO** JINCAO

**LS** 1973

**LA** Ger

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**L13 ANSWER 1 OF 388**

**AN** CA118(24):236879z

**TI** Polytetraalkylammonium and polytrialkylamine-containing ligands bonded to inorganic supports for removing and concentrating ions from solutions

**AU** Bruening, Ron; Tarbet, Bryon J.

**CS** Brigham Young University

**LO** USA


**PI** EP 480386 A1 15 Apr 1992

**DS** R: AT, BE, CH, DE, DK, ES, FR, GB, IT, LI, LU, NL, SE

**AI** EP 91-117160 8 Oct 1991

**PRAI** US 90-595309 10 Oct 1990

**IC** ICM B01J045-00

**ICS** B01J020-32; B01J041-04; B01J041-14

**SC** 48-1 (Unit Operations and Processes)

**DT** P

**CO** EPXXDW

**PY** 1992

**LA** Eng
Vibrational spectra and local symmetry of anions of perrhenate(ReO₄⁻) in cesium halide crystals
CS Kiev. Gos. Univ.
LO Kiev, Ukraine
SO Zh. Prikl. Spektrosk., 56(5-6), 757-62
SC 73-3 (Optical, Electron, and Mass Spectroscopy and Other Related Properties)
PY 1992
LA Russ

Extraction and adsorption of chloro complexes, perrhenate (ReO₄⁻), and tetrafluoroborate (BF₄⁻) with crown ethers and a crown ether polymer
AU Onishi, Hiroshi; Koshima, Hideko
CS Dep. Chem., Univ. Tsukuba
LO Tsukuba, Japan
SC 79-0 (Inorganic Analytical Chemistry)
SX 68
DT J
CO ZPSBAX
IS 0514-7506
PY 1992
LA Russ

The synthesis of high oxidation state metal complexes containing the tripodal ligand [(eta-5-C₅H₅)Co(P(OEt)₂(O)]₃- and the x-ray crystal structure of the cobalt-rhenium complex [(eta-5-C₅H₅)Co(P(OEt)₂(O)]₃ReO₃]. [Erratum to document cited in CA114(7):62343t]
AU Banbery, Hilary J.; Hussain, Wasif; Evans, Iona G.; Hamor, Thomas A.; Jones, Christopher J.; McCleverty, Jon A.; Schulte, Heinz Josef; Engels, Birgit; Klaeui, Wolfgang
CS Sch. Chem., Univ. Birmingham
LO Edgbaston/Birmingham B15 2TT, UK
SO Polyhedron, 11(3), 393
SC 29-13 (Organometallic and Organometalloid Compounds)
SX 75
DT J
TI Method and kit for radiolabeling monovalent antibody fragments and other proteins
AU Chang, Chien Hsing; Jones, Anastasia Lentine
CS Immunomedics, Inc.
LO USA
FI WO 9117440 A1 14 Nov 1991
RW: AT, BE, BJ, CF, CG, CH, CM, DE, DK, ES, FR, GA, GB, GR, IT, LU, ML, MR, NL, SE, SN, TD, TG
PRAI US 90-518707 7 May 1990
IC ICM G01N033-534
SC 15-1 (Immunochemistry)
DT P
CO EPXXD2
PY 1991
LA Eng

TI Potentiometric determination of perrhenates in products from synthesis of rhenium carbonyls
AU Ranski, A. P.; Bovykin, B. A.; Shram, V. P.; Gritsayuk, S. N.; Artyukhova, E. P.; Kolyada, V. I.; Shtemenko, A. V.
LO USSR
SC 79-6 (Inorganic Analytical Chemistry)
DT J
CO VKKCAJ
IS 0321-4095
PY 1990
LA Russ

TI Anion retention in soil: possible application to reduce migration of buried technetium and iodine: a review
AU Gu, B.; Schulz, R. K.
CS Dep. Soil Sci., Univ. California
LO Berkeley, CA, USA
SC 71-0 (Nuclear Technology)
SX 19
DT T
PY 1991
LA Eng

TI Correlation parameters for predicting anion-exchange extraction constants for 287 extraction systems containing 236 different anions on an ES computer with the program OPAG2
AU Mezhov, E. A.; Reymarov, G. A.; Khananishvili, N. L.; Schmidt, V. S.
LO Russia
SO Radiokhimiya, 34(1), 9-50
SC 68-2 (Phase Equilibriums, Chemical Equilibriums, and Solutions)
SX 20, 48, 54
DT J
CO RADKAU
IS 0033-8311
PY 1992
LA Russ
AN CA118(16):157019
TI Raman spectra, absolute Raman intensities, and electrooptical parameters of pertechnetate, perrenate, and periodate ions in aqueous solution
AU Eyssel, Hans H.; Kanellakopulos, Basil
CS Anorg.-Chem. Inst., Univ. Heidelberg
LO Heidelberg 6900/1, Germany
SO J. Raman Spectrosc., 24(2), 119-22
SC 73-3 (Optical, Electron, and Mass Spectroscopy and Other Related Properties)
SX 78
DT J
CO JRSAPF
IS 0377-0486
PY 1993
LA Eng

AN CA118(10):93069x
TI Reactivities of technetium complexes
AU Omori, Takashi
CS Sci. Coll., Tohoku Univ.
LO Sendai, Japan
SO Kyoto Daigaku Genshiro Jikkensho, [Tech. Rep.], KURRI-TR-362, 3-7
SC 78-0 (Inorganic Chemicals and Reactions)
SX 67
DT T
CO KDGDHD
IS 0287-9808
PY 1991
LA Japan

AN CA118(8):68680
TI Technetium-99 removal from process solutions and contaminated groundwater
AU Del Cul, G. D.; Bostick, W. D.; Trotter, D. R.; Osborne, P. E.
CS Dep. Chem., Oak Ridge K-25 Site
LO Oak Ridge, TN 37831-7274, USA
SO Sep. Sci. Technol., 28(1-3), 551-64
SC 71-11 (Nuclear Technology)
SX 61, 66
DT J
CO JLCHD8
IS 0149-6395
PY 1993
LA Eng

AN CA118(6):47723h
TI Adsorption of technetium from acidic solutions
AU Ito, K.
CS Tohoku Univ.
LO Sendai, Japan
SC 71-11 (Nuclear Technology)
SX 66
DT T
CO KDGDHD
IS 0287-9808
PY 1991
LA Japan

AN CA118(6):47585q
TI Nuclear reactions of technetium with possible availability and new approach to technetium analysis by laser photoacoustic spectroscopy
AU Yoshihara, K.
CS Sci. Coll., Tohoku Univ.
LO Sendai, Japan
SC 71-6 (Nuclear Technology)
SX 70, 73, 79
DT T
CO KDGDHD
IS 0287-9808
PY 1991
LA Japan

AN CA118(6):47351k
TI The solution chemistry of technetium on the radioactive waste disposal
AU Kanno, T.
CS Tohoku Univ.
LO Sendai, Japan
SC 71-0 (Nuclear Technology)
SX 53, 66
DT T
CO KDGDHD
IS 0287-9808
PY 1991
LA Japan

AN CA117(18):178285u
TI The determination of charge of anionic technetium-99m radiopharmaceuticals
AU Nowotnik, D. P.; Riley, A. L. M.
CS Amersham Int. plc
LO Amersham HP7 9LL, UK
SO J. Liq. Chromatogr., 15(12), 2165-74
SC 63-8 (Pharmaceuticals)
SX 8
DT J
CO JLCHD8
IS 0148-3919
PY 1992
LA Eng
The behavior of decomposition products of hydrazine in PUREX process

The behavior of pertechnetate ion adsorption shown by activated carbons derived from different sources.

Characterization of grouted low-level waste to support performance assessment.

Aqueous partial molar heat capacities and volumes for sodium pertechnetate and sodium perhenate.

L14 ANSWER 30 OF 308
TI Novel technetium-99m complexes for radiopharmaceutical imaging agents
AU Dunn, T. Jeffrey; Nosco, Dennis; Woulfe, Steven; Dean, Richard;
Wester, Dennis
CS Mallinckrodt, Inc.
LO USA
SO PbInt. A pl., 119 p.
PI WO 9000854 A1 18 Feb 1990
DS W: AU, JP
RW: AT, BE, CH, DE, FR, GB, IT, LU, NL, SE
AI WO 89-US3066 18 Jul 1989
PRAI US 88-221099 19 Jul 1988
US 89-315168 24 Feb 1989
IC ICM C07F013-00;
ICS A61K049-02; C07C215-50;
C07C251-08; C07F005-04;
C07F009-50
SC 8-9 (Radiation Biochemistry)
SX 25, 78
DT P
CO PIIXD2
PY 1990
LA En
OS MÄRPAT 114:77949
=> s 14333-20-1 and environment?
308 14333-20-1
75860 ENVIRONMENT?
L7 1 14333-20-1 AND ENVIRONMENT?
=> d 17
L7 ANSWER 1 OF 1
TI The chemical speciation of technetium in the ***environment***. A literature survey
AU Sparkes, S. T.; Long, S. E.
LO Oxfordshire OX11 0RA, UK
SO U. K. At. Energy Auth., Harwell Lab., [Rep.] AERE-R, AERE R 12743,
32 pp.
SC 71-0 (Nuclear Technology)
DT T
CO UKRGAL
IS 0436-9734
PY 1988
LA En
=> s 14333-20-1 and separat?
308 14333-20-1
95976 SEPARAT?
L8 12 14333-20-1 AND SEPARAT?
=> d 18 ti,au,so,py

L8 ANSWER 1 OF 12
TI ***Separation*** of anionic and cationic compounds of biomedical interest by high-performance liquid chromatography on porous graphitic carbon
AU Gu, Guanghua; Lim, C. K.
SO J. Chromatogr., 515, 183-92
PY 1990

L8 ANSWER 2 OF 12
TI ***Separation*** of the noble metals ruthenium and palladium from a nitric acid solution of a nuclear fuel reprocessing stream containing complexing agents
AU Ghafourian, Hossein
PY 1989

L8 ANSWER 3 OF 12
TI Electronic interaction chromatography on porous graphitic carbon.
***Separation*** of [99mTc]pertechnetate and permethenate anions
AU Lim, C. K.
SO Biomed. Chromatogr., 3(2), 92-3
PY 1989

L8 ANSWER 4 OF 12
TI ***Separation*** of radionuclides from water by magnesium oxide adsorption
AU Tseng, Chia Lian; Lo, Jem Mau; Yeh, Si Jung
PY 1987

L8 ANSWER 5 OF 12
TI Silica gel supported microcrystalline zirconium phosphate ion exchanger (Si-ZrP) and its application in chemical ***separations***. III. ***Separation*** of alkali and transition metal ions
AU Le Van So; Szirtes, L.
SO J. Radioanal. Nucl. Chem., 99(1), 55-60
PY 1986

L8 ANSWER 6 OF 12
TI ***Separation*** of uranium from technetium in recovery of spent nuclear fuel
AU Friedman, Horace A.
PY 1985

Contract 669HH0013-9Z
Final Report page 56
TI Extraction of some single-charged oxo anions by tetraoctylammonium nitrate
AU Dzhigirkhanov, M. A.; Matyunin, Yu. I.
So Deposited Doc., VINITI 575-82, 365-9
Avail. VINITI
PY 1981

L9 28 14333-20-1 AND EXTRACT?

L10 25 L9 NOT L8

L10 ANSWER 1 OF 25
TI Correlation parameters for predicting anion-exchange extraction constants for 287 extraction systems containing 236 different anions on an ES computer with the program OPAC2
AU Mezhov, E. A.; Reymarov, G. A.; Khananishvili, N. L.; Schmidt, V. S.
So Radiokhimija, 34(1), 9-50
PY 1992

L10 ANSWER 2 OF 25
TI The behavior of decomposition products of hydrazine in PUREX process
AU Zil'berman, B. Ya.; Lelyuk, G. A.; Mashkin, A. N.; Fedorov, Yu. S.
SO Process Metall., 7A(Solvent Extr. 1990, Pt. A), 759-64
PY 1992

L10 ANSWER 3 OF 25
TI Extraction of pertechnetate anion as a ligand in a cerium(IV) tributyl phosphate complex
AU Akopov, G. A.; Krinitsyn, A. P.; Tsarenko, A. F.
SO J. Radioanal. Nucl. Chem., 140(2), 349-56
PY 1990

L10 ANSWER 4 OF 25
TI Alkyl and arylphosphonium nitrate salts as extractants for pertechnetate
AU Tse, Pui Kwan; Horwitz, E. Philip
SO Solvent Extr. Ion Exch., 8(2), 353-60
PY 1990
L10 ANSWER 5 OF 25
TI Preferential solvation of single ions and the TBP- ***extraction*** behavior of acids, uranyl pertechnetate and uranyl nitrate
AU Kanellakopulos, B.; Neck, V.; Kim, J. I.
SO Radiochim. Acta, 48(3-4), 159-63
PY 1989

L10 ANSWER 6 OF 25
TI Studies on the ***extraction*** of TcO4- from solutions of mono- and bivalent metal hydroxides by use of Kryptofix-22 in 1,2-dichloroethane
AU Jalhoom, Muayed G.
PY 1989

L10 ANSWER 7 OF 25
TI Antimony ***extraction*** from nitric acid solutions by tributyl phosphate. III. The influence of iodide and pertechnetate ions on the ***extraction*** of antimony from nitric acid solutions by tributyl phosphate
AU Lakaev, V. S.; Smelow, V. S.
SO Radiokhimiya, 30(4), 481-4
PY 1988

L10 ANSWER 8 OF 25
TI ***Extraction*** of pertechnetate ions by use of crown ethers from sulfuric acid solutions
AU Jalhoom, M. G.
PY 1986

L10 ANSWER 9 OF 25
TI A convenient method on the methyl-ethylketone ***extraction*** of pertechnetate (99mTcO4-)
AU Lee, Jong Du; Lee, Byung Hun
SO Pangssason Pango Hakhoechi, 9(2), 103-11
PY 1984

L10 ANSWER 10 OF 25
TI Solubility and ***extraction*** of tetraphenylarsonium pertechnetate [[C6H5]4AsTcO4]; thermodynamic investigations
AU Neck, V.; Kanellakopulos, B.; Kim, J. I.
PY 1985

L10 ANSWER 11 OF 25
TI ***Extraction*** of nitric acid, technetium and palladium by bidentate carbamoylmethylphosphonates
AU Gorski, B.; Kuca, L.; Petrzelova, H.
SO J. Radioanal. Nucl. Chem., 91(2), 305-13
PY 1985

L10 ANSWER 12 OF 25
TI Co- ***extraction*** of pertechnetate with zirconium(IV) in the TBP-nitric acid system
AU Jassim, T. N.; Persson, G.; Liljenzorn, J. O.
SO Solvent Extr. Ion Exch., 27, 1079-92
PY 1984

L10 ANSWER 13 OF 25
TI ***Extraction*** potential of trialkylsulfonium nitrates
AU Dzhigirkhanov, M. S.; Silant'ev, A. I.
SO Deposited Doc., VINITI, 575-82, 370-4
PY 1981

L10 ANSWER 14 OF 25
TI ***Extraction*** of some singly and doubly charged anions by trialkylsulfonium nitrate
AU Dzhigirkhanov, M. S.; Abramov, A. A.; Silant'ev, A. I.; Iofa, B. Z.
SO Radiokhimiya, 25(1), 128-30
PY 1983

L10 ANSWER 15 OF 25
TI The modeling of technetium ***extraction*** in uranium cycle of PUREX-type process
AU Kadroba, J.; Macasek, F.
PY 1982

L10 ANSWER 16 OF 25
TI Quantitative description using linear relationships of free energies for a new set of anion-exchange ***extraction*** constants for a series of single-charged anions
AU Shmidt, V. S.; Rybakov, K. A.; Rubisov, V. N.
SO Zh. Neorg. Khim., 27(6), 1519-22
PY 1982

L10 ANSWER 17 OF 25
TI The ***extraction*** of technetate(VI) ion and palladium(II) by dihexyl-N,N-diethylcarbamoylmethylphosphonate from nitric acid
AU McIsaac, L. D.
PY 1982
L10 ANSWER 18 OF 25
TI ***Extraction*** of pertechnetate, molybdate, and molybdophosphate ions by some oxygen-containing solvents in acid solution—a new procedure of production of technetium-99m for medical use
AU Misak, N. Z.; El-Asrag, H. A.; El-Kolaly, M.; Hallaba, E.
SO Microchem. J., 26(3), 316-28
PY 1981

L10 ANSWER 19 OF 25
TI Simulation of interfacial two-step consecutive reactions by diffusion in the mass-transfer kinetics of liquid-liquid ***extraction*** of metal cations
AU Danesi, P. R.; Vandegrift, G. F.; Horwitz, E. P.; Chiarizia, R.
SO J. Phys. Chem., 84(26), 3582-7
PY 1980

L10 ANSWER 20 OF 25
TI ***Extraction*** of pertechnetate anion as a ligand in metal complexes with tributylphosphate
AU Macasek, F.; Kadrabova, J.
SO J. Radioanal. Chem., 51(1), 97-106
PY 1979

L10 ANSWER 21 OF 25
TI ***Extraction*** of pertechnetate with tri(alkyl)methylammonium nitrates. Kinetics and mechanism in the system o-xylene-nitric acid
AU Dyrkacz, Gary R.; Vandegrift, G. F.; Thomsen, M. W.; Horwitz, E. P.
SO J. Phys. Chem., 83(6), 670-5
PY 1979

L10 ANSWER 22 OF 25
TI ***Extraction*** of technetium(VII) from nitrate solutions by tri-n-octylamine solutions
AU Volk, V. I.; Rozen, A. M.; Barabash, A. I.
SO Radiokhimiya, 18(2), 243-6
PY 1976

L10 ANSWER 23 OF 25
TI Organic oxides as ***extractants*** for metal anions
AU Krasovec, F.; Klofutar, C.
PY 1967

L10 ANSWER 24 OF 25
TI Properties of anions controlling the ***extractability*** of their associates with triarylmethane dyes
AU Lomonosov, S. A.; Nikolaev, A. V.
SO Zh. Strukt. Khim., 8(2), 216-20
PY 1967

L10 ANSWER 25 OF 25
TI Solvent ***extraction*** and spectrophotometric determination of the pertechnetate ion with Methyl Violet
AU Fujinaga, Taitiro; Koyama, Mutsuo; Kanchiku, Yoshihiko; Tsurubo, Shigeo
PY 1967

CAS Online Search, April 1994

CAS Online Search 5/11/94

=> 14333-24-5 and extract? and 1993-1994/py
396 14333-24-5
86662 EXTRACT?
488590 1993-1994/PY

=> d 11
L1 ANSWER 1 OF 1 CA
AN CA119(18):189552w CA
TI Solvent ***extraction*** of rhenium(VII) with crown ethers and some univalent cations
AU Zhang, Xianxin; Zhou, Zhixian; Ma, Shejun; Shu, Chang
CS Dep. Chem., Zhengzhou Univ.
SO Solvent Extr. Ion Exch., 11(4), 585-601
SC 68-2 (Phase Equilibriums, Chemical Equilibriums, and Solutions)
SX 69
DT J
CO SEIEDB
IS 0736-6299
PY 1993
LA Eng
***Extraction*** of technetium(VI) from uranium(VI) in nitric acid system by primary amine - n-heptane solution

AU Ito, K.
LO Sendai 980, Japan
SO J. Radioanal. Nucl. Chem., 171(2), 371-82
SC 71-5 (Nuclear Technology)
DT J
CO JRNCDM
IS 0236-5731
PY 1993
LA Eng

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***Recovery*** and mutual separation process of fission-produced noble metals(II) - dissolution of the simulated fission-produced noble metal alloys (molybdenum-***rhenium***-ruthenium-rhodium-palladium alloys) in boiling nitric acid solution

AU Matsui, Tsunoe; Sasaki, Ryoichi
CS Dep. Nucl. Eng., Nagoya Univ.
LO Nagoya 464-01, Japan
SC 71-11 (Nuclear Technology)
SX 56
DT C
CO 59PFAE
PY 1993
LA Eng

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Wet precipitator case histories

AU Ojanpera, R.; Gamble, B.
CS Joy Technol. Canada Inc.
LO Kitchener, ON N2C 2C8, Can.
LO Montreal, Can.
SC 59-4 (Air Pollution and Industrial Hygiene)
SX 47, 54, 56
DT C
CO 59ODA3
PY 1993
LA Eng

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Process for simultaneous ***recovery*** of precious metals and tertiary phosphine from spent catalysts using tellurium

AU De Oliveira, Bandarra Joao J.; De Carvalho, Alexandre J. G.; Heggie, William
CS Plurichemie Anstalt
LO Liechtenstein
P1 CA 2086384 A
AI CA 92-2086384 921229
PRA1 PT 91-99958 911231
PT 91-99959 911231
SC 54-4 (Extractive Metallurgy)
SX 49, 51
DT P
CO CPXWEB
PY 1993
LA Eng

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Contract 669HH0013-9Z
L3 ANSWER 5 OF 13 CA
AN CA120(6):57801n CA
TI Recovery*** of rhenium*** from nonferrous metallurgy wastes
IN Mordalski, Jerzy; Lach, Jan; Szmygin, Marian; Banas, Boleslaw; Czarny, Joanna; Kowal, Witold
PA KGHM "Polska mied" - SA. Oddzial-Zaklad Doswiadczalny
LO Pol.
SO Pol., 12 pp. Abstracted and indexed from the unexamined application.
PI PL 160950 B1 930531
AI PL 88-273322 880624
SC 49-1 (Industrial Inorganic Chemicals)
SX 55
DT P
CO POXXA7
PY 1993
LA Pol

L3 ANSWER 6 OF 13 CA
AN CA120(4):33815u CA
TI Radiochemical separation of thallium(1) using cerium(IV) molybdate as an ion exchanger
AU Bhagat, R. D.; Turel, Z. R.
SC 49-1 (Industrial Inorganic Chemicals)
SX 66, 68, 71, 78, 79
DT J
CO SSTEDS
IS 0149-6395
PY 1994
LA Eng

L3 ANSWER 7 OF 13 CA
AN CA120(2):22699h CA
TI A procedural modification for enhanced recovery*** of precious metals (gold, platinum group elements) following nickel sulfide fire assay and tellurium coprecipitation: applications for analysis of geological samples by inductively coupled plasma mass spectrometry
AU Sun, Min; Jain, Jinesh; Zhou, Meifu; Kerrich, Robert
CS Dep. Geol. Sci., Univ. Saskatchewan
LO Saskatoon, SK S7N 0W0, Can.
SO Can. J. Appl. Spectrosc., 38(4), 103-8
SC 79-6 (Inorganic Analytical Chemistry)
SX 53
DT J
CO CJSPM
PY 1993
LA Eng

L3 ANSWER 8 OF 13 CA
AN CA119(26):275600s CA
TI Reclamation of tungsten from activated fusion reactor components
AU Murphy, D.; Warren, S.; Butterworth, G. J.
CS Johnson Matthey plc
LO Royston, Hertfordshire, SG8 5HE, UK
SC 54-2 (Extractive Metallurgy)
SX 71
DT J
CO FEDEEE
IS 0920-3796
PY 1993
LA Eng

L3 ANSWER 9 OF 13 CA
AN CA119(18):185191e CA
TI Geochemical prospecting by selective leaching followed by quantitative analysis
IN Clark, John Robert
LO USA
PI WO 9309223 A1 930513
DS W: AU. BR. CA. FI. NO. RU RW: AT. BE. CH. DE. DK. ES. FR. GB. GR. IE. IT. LU. MC. NL. SE
AI WO 92-US8732 921013
PRAI US 91-788543 911106
SC 53-2 (Mineralogical and Geological Chemistry)
DT P
CO PIXD2
PY 1993
LA Eng

L3 ANSWER 10 OF 13 CA
AN CA119(16):163796d CA
TI Recovery*** of hydrocarbons from contaminated or waste petroleum and petroleum products by using a surface-treated permeable inorganic membrane
IN Slepky, William C.; Wiesman, Larry F.; Thomas, Kenneth M.; Goodboy, Kenneth P.
PA Aluminum Co. of America
LO USA
SO U.S. 8 pp.
PI US 5209838 A 930511
AI US 91-772205 911007
SC 51-2 (Fossil Fuels, Derivatives, and Related Products)
SX 60
DT P
CO USXXAM
PY 1993
LA Eng

Contract 669HH0013-9Z
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Inclusions of the \( \text{CHI} \)-phase and structural ***recovery*** in ternary nickel-titanium based alloys

**AU** Khundzhua, A. G.; Sorokin, A. V.

**CS** Mosk. Gos. Univ.

**LO** Moscow, Russia


**SC** 56-8 (Nonferrous Metals and Alloys)

**DT** J

**CO** IRAFEO

**PY** 1993

**LA** Russ

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Metal ***recovery*** from waste catalysts used in exhaust gas treatment

**AU** Giegerich, Heinz; Hensel, Clemens

**CS** EAR European Autocat Recycling GmbH

**LO** Germany


**PI** DE 4122717 A1 930121

**AI** DE 91-4122717 910709

**SC** 60-4 (Waste Treatment and Disposal)

**SX** 51, 54, 59, 67

**DT** P

**CO** GWXXBX

**PY** 1993

**LA** Ger

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Selective ***recovery*** of ***rhenium*** from gas-scrubbing solutions of molybdenite roasting using direct precipitation and separation on resins

**AU** Blazy, P.; Jdid, E. A.; Floreancig, A.; Mottet, B.

**CS** Cent. Recher. sur la Valorisation Miner., ENSG

**LO** Vandoeuvre 54501, Fr.

**SO** Sep. Sci. Technol., 28(11), 2073-96

**SC** 54-2 (Extractive Metallurgy)

**DT** J

**CO** SSTEDS

**IS** 0149-6395

**PY** 1993

**LA** Eng

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Method and apparatus for concentration and purification of technetate-99mTc solutions

**AU** Seifert, Sepp; Schneider, Frauke; Wagner, Gerhard

**CS** Forschungszentrum Rossendorf E.V.; Verein fuer Kernverfahrenstechnik und Analytik E.V.

**LO** Germany

**SO** Ger. Offen., 5 pp.

**PI** DE 4229327 A1 940303

**AI** DE 92-4229327 920902

**SC** 71-6 (Nuclear Technology)

**DT** P

**CO** GWXXBX

**PY** 1994

**LA** Ger

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Advanced chemical separations in support of the Clean Option Strategy

**AU** Horwitz, E. Philip; Dietz, Mark L.; Diamond, Herbert; Rogers, Robin D.; Leonard, Ralph A.

**CS** Chem. Div., Argonne Natl. Lab.

**LO** Argonne, IL 60439-4831, USA


**SC** 71-11 (Nuclear Technology)

**DT** C

**CO** 59PFAE

**PY** 1993

**LA** Eng
L6 ANSWER 2 OF 7 CA
AN CA120(4):44737w CA
TI Ion-selective electrode for determining perrhenate ions in molybdenum-containing solutions
IN Babenko, Nadezhda L.; Blokh, M. Sh.; Tashuta, Galina N.
PA Institute of Metallurgy and Ore Beneficiation, Academy of Sciences, Kazakhstan SSR.

LO USSR
PI SU 1790764 A3 930123
AI SU 90-4814925 900416
SC 79-2 (Inorganic Analytical Chemistry)
DT P
CO URXXAF
PY 1993
LA Russ

L6 ANSWER 3 OF 7 CA
AN CA120(4):38598k CA
TI Electronic structures of d0 complexes by the DV-X, alpha. method
AU Mukoyama, Takeshi; Adachi, Hirohiko
CS Institute for Chemical Research, Kyoto University, Uji
LO Kyoto 611, Japan
SC 65-3 (General Physical Chemistry)
DT J
CO CHPLBC
IS 0009-2614
PY 1993
LA Eng

L6 ANSWER 4 OF 7 CA
AN CA119(21):224277j CA
TI Selective alteration of antibody immunogenicity
IN Sykes, Thomas R.; Reddish, Mark; Baum, Richard P.; Noujaim, Antoine A.
PA Biomira Inc.
LO Can.
PI WO 9318792 A1 930930
DS W; AU, CA, FI, JP, NO, US
RW: AT, BE, CH, DE, DK, ES, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE
AI WO 93-CAl10 930318
PRAI US 92-853605 920318
SC 10-3 (Immunonchemistry)
DT P
CO PIKXD2
PY 1993
LA Eng

L6 ANSWER 5 OF 7 CA
AN CA119(12):126213r CA
TI Heat capacities of tetrahedral oxoanions in aqueous solutions at 298 K
AU Drakin, S. I.; Popova, O. V.

LO Moscow, Russia
SO Zh. Fiz. Khim., 67(3), 606-8
SC 69-2 (Thermodynamics, Thermochemistry, and Thermal Properties)
DT J
CO ZFKHA9
IS 0044-4537
PY 1993
LA Russ

L6 ANSWER 6 OF 7 CA
AN CA118(22):215319b CA
TI Highly selective monoalkylen glycol catalysts
IN Fiskner, Matthew William
PA Union Carbide Chemicals and Plastics Technology Corp.
LO USA
PI EP 529726 A1 930303
DS R: BE, DE, ES, FR, GB, IT, NL
AI EP 92-202570 920821
PRAI US 91-749332 910823
SC 45-4 (Industrial Organic Chemicals, Leather, Fats, and Waxes)
SX 67
DT P
CO EPXXDW
PY 1993
LA Eng

L6 ANSWER 7 OF 7 CA
AN CA118(16):157019r CA
TI Raman spectra, absolute Raman intensities, and electrooptical parameters of pertechnetate, perrhenate, and periodate ions in aqueous solution
AU Eysel, Hans H.; Kanellakopoulos, Basil
CS Anorg.-Chem. Inst., Univ. Heidelberg
LO Heidelberg 6900/1, Germany
SO J. Raman Spectrosc., 24(2), 119-22
SC 73-3 (Optical, Electron, and Mass Spectroscopy and Other Related Properties)
SX 78
DT J
CO JRSPAF
IS 0377-0486
PY 1993
LA Eng
Method and apparatus for concentration and purification of pertechnetate-99mTc solutions

Seifert, Sepp; Schneider, Frauke; Wagner, Gerhard
Forschungszentrum Rossendorf E.V.; Verein fuer Kernverfahrenstechnik und Analytik E.V.

Adsorption of pertechnetate on an anion exchange resin

Kawasaki, Mikio; Omori, Takashi; Hasegawa, Kunihiko

Partitioning of actinides from acid waste solutions of Purex origin using CMPO

Mukovama, Takeshi; Adachi, Hirohiko
Institute for Chemical Research, Kyoto University, Uji

Accumulation of technetium by cyanobacteria

Garnham, Geoffrey W.; Codd, Geoffrey A.; Gadd, Geoffrey M.
Dep. Biol. Sci., Univ. Dundee

Ligands for improved macromolecule radiolabeling

Bridger, Gary James; Hernandez, Pedro Emilio; Higgins, John David III; Larsen, Scott Kenneth
Johnson Matthey PLC

Electron structures of d0 complexes by the DV-Xα method

Mukoyama, Takeshi; Adachi, Hirohiko
Institute for Chemical Research, Kyoto University, Uji

Accumulation of technetium by cyanobacteria

Garnham, Geoffrey W.; Codd, Geoffrey A.; Gadd, Geoffrey M.
Dep. Biol. Sci., Univ. Dundee

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