A SISAK Extraction System for Chemical Studies of Hassium

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Outline

- SISAK system
- Element 108, Hs
- Developing stage at Oslo Cyclotron Laboratory (OCL)
- Pilot experiment at GSI
- Comparing Ru and Os, Hs predictions
SISAK system

- Fast online automated solvent extraction system suitable for study of short-lived isotopes with one-atom-at-a-time sensitivity.

  - Successfully performed several 4-s $^{257}$Rf chemistry experiments.
  - Successfully tested detection of 4-s $^{258}$Db.
Previous Hs experiments

- Formation of HsO$_4$ analogous to OsO$_4$ and RuO$_4$ (gas phase experiments) [1,2]
- Evidence for formation of hassate [HsO$_4$(OH)$_2$]$^{2-}$ analogous to osmate [OsO$_4$(OH)$_2$]$^{2-}$ (gas phase experiments) [3]

System Developed at OCL

System developed based on known chemical properties of Hs:

- Transportation is based on in situ formation of volatile tetroxides of group VIII elements.

- Solvent extraction based on formation of hydroxo complexes of tetroxides.
Os experiments at OCL

2.7-min $^{181}\text{Os}$ produced from 45 MeV $^3\text{He}$ on W-target.
Os forms OsO$_4$ in a He/O$_2$ gas jet.
Os experiments at OCL

OsO$_4$ dissolved in diluted NaOH and extracted into toluene.
Results of Oslo experiments

![Graph showing D value vs NaOH conc. (M)]

- Os Batch experiments
- OCL Os SISAK experiment

D value vs NaOH conc. (M)
D value vs. conc. of NaOH

\[
D = \frac{[\text{OsO}_4]_{\text{org}}}{[\text{OsO}_4]_{\text{aq}} + [\text{OsO}_4(\text{OH})^-] + [\text{OsO}_4(\text{OH})_2]^{2-}}
\]

\[
D = \frac{K_D}{1 + K_1[\text{OH}^-] + K_1 K_2[\text{OH}^-]^2}
\]

Where \( K_D \) is the distribution constant of OsO\(_4\) between toluene and water and \( K_1 \) and \( K_2 \) are the equilibrium constant for the complex formation reactions.
Fitting of the results

\[ D = \frac{K_D}{1 + K_1[OH^-] + K_1K_2[OH^-]^2} \]

- \( K_D = 11 \pm 5 \)
- \( K_1 = (1 \pm 0.5) \times 10^4 \)
- \( K_2 = 12 \pm 8 \)
GSI experiments

- Pilot experiment performed at GSI to test the entire SISAK setup with double α-detector arrays.
The setup at GSI
α emitting Os isotopes at GSI experiments

<table>
<thead>
<tr>
<th>Isotope</th>
<th>$^{172}$Os</th>
<th>$^{173}$Os</th>
<th>$^{174}$Os</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mode</td>
<td>$\varepsilon + \beta^+$</td>
<td>$\alpha$</td>
<td>$\varepsilon + \beta^+$</td>
</tr>
<tr>
<td>Branching (%)</td>
<td>99.02</td>
<td>1.02</td>
<td>99.979</td>
</tr>
<tr>
<td>Half-life</td>
<td>45 s</td>
<td>22.4 s</td>
<td>19.2 s</td>
</tr>
</tbody>
</table>
Results of GSI experiments

![Graph showing D value vs. NaOH concentration (m)].

- **Os Batch experiments**
- **OCL gamma Os SISAK**
- **GSI alpha Os SISAK**
Transport time measurements

Performed by pulse bombardment of the target followed by a break (beam pulse = 10 s, break = 190 s) repeated for about 1 hour
Transport time curve

Normalized count rate vs. time since start of beam pulse (s)

- Scintillation flow: 0.2 mL/s
- Scintillation flow: 0.4 mL/s
Transport time measurement

- Both $^{173}$Os and $^{174}$Os are transported to the degasser.
- Both are short-lived. Thus, the $^{173}$W and $^{174}$Re daughter products were measured.

$$\frac{792/0.5^{45}}{3801} = \frac{601/0.5^{22.4}}{1519}$$

- From this the transport time $= 41$ s was calculated.
The Yield Measurements

- Was measured by calculating the ratio of activity of $^{174}\text{Re}$ the daughter of $^{174}\text{Os}$ in an Al catcher foil to its activity in the samples from degasser.

- Yield for the transferring from RTC to the liquid phase was $(75\pm15)\%$ independent of oven temperature.
Off-line SISAK experiment

Toluene

Mixer

Centrifuge

Heat exchanger 85 °C

Ce(SO₄)₂ 0.03 M
H₂SO₄ 0.2 M
+ tracer amounts of Os* and Ru* compounds

Raffinate

Mixer

NaOH solution

Centrifuge

Organic phase

Aqueous phase

To the γ detectors
Comparing Ru and Os

![Graph showing D value vs NaOH concentration for various experiments.]

- OCL Os online SISAK exp.
- Ru taken from [1]
- Os offline SISAK exp.
- Ru offline SISAK exp.

Comparing Ru and Os

- D value for RuO$_4$ is higher than for OsO$_4$
- According [1] predicted trend for the formation of Na$_2$[MO$_4$(OH)$_2$] in the reaction:
  \[ 2\text{NaOH} + \text{HsO}_4 \rightarrow \text{Na}_2[\text{HsO}_4(\text{OH})_2] \]
  in group 8 is:
  \[ \text{Os} > \text{Hs} >> \text{Ru} \]
- The trend in D value then can be predicted to be like this:
  \[ \text{Ru} >> \text{Hs} > \text{Os} \]

Conclusion

- In this work an extraction system for chemical study of Hs was developed using Os as a model.
- The full system was tested using $\alpha$-emitting Os.
- The system is basically ready for an Hs experiment.
Acknowledgement

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