PRODUCTION OF SCANDIUM AND Al-Sc ALLOY BY USING CaCl₂ MOLTEN SALT

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Introduction

- What is Scandium?
- Properties of Sc
- Light weight - Expensive
- Chemically reactive
- Sc₂O₃ is one of the most stable oxides on earth

Metallothermal Reduction

Thermodynamic analysis

Table  Minerals containing Sc

<table>
<thead>
<tr>
<th>Mineral</th>
<th>Sc content (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monazite</td>
<td>0.002</td>
</tr>
<tr>
<td>Thortveitite</td>
<td>0.003</td>
</tr>
</tbody>
</table>

Table  Chemical composition of Thortveitite

- Thortveitite contains a large amount of Sc; however, such minerals are not used as a source of Sc because they are scarce.

Currently, Sc is produced in the form of oxide (Sc₂O₃) from rare earth ores or as a byproduct of uranium mill tailings. Recently, Ni smelting has changed from a pyrometallurgical process to a hydrometallurgical process that can recover a large amount of Sc₂O₃ at a low cost.

Table  Chemical composition of Thortveitite

<table>
<thead>
<tr>
<th>Element</th>
<th>Sc</th>
<th>Mg</th>
<th>Si</th>
<th>Al</th>
<th>Ca</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass %</td>
<td>0.06</td>
<td>0.01</td>
<td>0.01</td>
<td>0.01</td>
<td>0.01</td>
</tr>
</tbody>
</table>

Figure  Ellingham diagram of selected oxides.

Metal halide lamp

Other:

- Catalysts
- Laser crystals

Sc is mainly used as an alloying element for Al alloy. Al-Sc alloy is expected to be used as a structural material for aircraft etc.

Metallothermal Reduction

- Reduction: Sc₂O₃ (s) + 3 Ca (l) → 2 Sc (s) + 3 CaO (l)
- Reduction and alloying: Sc₂O₃ (s) + Al (l) → Al-Sc alloy (l) + 3 CaO (l)

Table  Experimental conditions for the metallothermal reduction

<table>
<thead>
<tr>
<th>Reduction temperature (°C)</th>
<th>Reaction capsule</th>
<th>TIG weld</th>
<th>Ta crucible</th>
<th>Stainless steel</th>
<th>Ca shots</th>
<th>Ti sponge</th>
</tr>
</thead>
<tbody>
<tr>
<td>1273</td>
<td>Stainless steel</td>
<td>TIG weld</td>
<td>Ta crucible</td>
<td>Stainless steel</td>
<td>Ca shots</td>
<td>Ti sponge</td>
</tr>
</tbody>
</table>

Results

- Reduction temperature: T = 1273 K
- Holding time: t = 6 h

A complex oxide (CaSc₂O₅) was formed and reduction was incomplete.

Conclusion

It was demonstrated that Ag-Y alloy could be produced by the electrolysis of CaCl₂-Y₂O₃ molten salt. The electrolysis cell must be improved to prevent the contamination of the molten salt by Fe.

Molten Salt Electrolysis

- Anode: C + x O²⁻ → CO₂ + 2e⁻
- Cathode: Sc₂O₃ + 6 e⁻ → 2 Sc + 3 O²⁻

Table  Theoretical decomposition voltage

<table>
<thead>
<tr>
<th>Voltage (V)</th>
<th>Current (A)</th>
<th>Time (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.26</td>
<td>0.15</td>
<td>0.26</td>
</tr>
</tbody>
</table>

Conclusion

- Metallothermic reduction
- Development of a new technique for preventing Ca contamination of Al-Sc alloy.
- Al-Sc alloy was directly produced from Sc₂O₃ by using Al as the collector metal; however, excess Ca reductant remained in the alloy sample.

Future study

- Metallothermic reduction
- Development of a new technique for preventing Ca contamination of Al-Sc alloy.
- Molten salt electrolysis

It is demonstrated that Ag-Y alloy could be produced by the electrolysis of CaCl₂-Y₂O₃ molten salt. The electrolysis cell must be improved to prevent the contamination of the molten salt by Fe.

- Conversion into fluoride: Sc₂O₃ + 6 HF → ScF₃ + 3 H₂O
- Reduction: 2 ScF₃ + 3 CaCl₂ → 2 Sc + 3 CaCl₂

Sc₂O₃ is converted into ScF₃ because it is thermodynamically stable. Further, it is difficult to reduce Sc₂O₃ to metallic Sc even by using Ca as a reductant.

- Disadvantages
  - The production cost is high because an expensive reaction apparatus is required for handling the fluoride.
  - Contamination from the crucible cannot be prevented due to the high-temperature reaction.

- Purpose of this study
  - To develop a new process that can produce Sc metal or Al-Sc alloy directly from Sc₂O₃ at temperatures lower than those used in the conventional process.

Fig. Schematic illustration of experimental apparatus for the metallothermal reduction experiment.

Results

- Electrolysis

Conclusion

It was demonstrated that Ag-Y alloy could be produced by the electrolysis of CaCl₂-Y₂O₃ molten salt. The electrolysis cell must be improved to prevent the contamination of the molten salt by Fe.

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