Technical Possibilities to Support Separation of Radioactive Elements from Metallic Waste

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Content

• Short about Swerea MEFOS
• Thermodynamics: what is possible and what is not possible
• Metallurgical Principle of Metal Recycling and Recovery
• EAF - The conventional steel scrap meltshop
• Tramp elements vs radioactive scrap
• Scrap cleaning projects at Swerea MEFOS
Swerea MEFOS – 50 years of excellence

- Nordic
- Associated members
- Applied research
- New technology
- Pilot testing
- Contract research
Pilot Plant

Media systems: air, oil, O₂, N₂, propane

Blast furnace model

Induction furnaces

Ladle preheaters

Universal converter

Electric arc furnace

DC furnace

Process simulation and control

Clients from all over the world
LKAB:s Experimental Blast Furnace

- Owner: LKAB
- Aim: Development of pellets
  Know-how of operation with pellets and sinter
- Special project: ULCOS – TGR (EU)

Spring 2012

Japanese Course 50 comes to Sweden
Decreasing the emissions of carbon dioxide from hot metal production
Thermodynamics

- Gibbs free energy, $\Delta G = \Delta H - \Delta ST$
- Selectivity: Ca-O-Fe, CaO-SiO2-FeO
- Nobleness – Distribution (Fe/slag/dust)
- The Ellingham diagrams and how to apply them in your daily operation
- Activity
# Chemical Reactions vs the Periodic System

<table>
<thead>
<tr>
<th></th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
<th>V</th>
<th>VI</th>
<th>VII</th>
<th>VIII</th>
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<td>2</td>
<td>B</td>
<td>C</td>
<td>N</td>
<td>O</td>
<td>F</td>
<td>Ne</td>
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<tr>
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<td>Be</td>
<td>Al</td>
<td>Si</td>
<td>P</td>
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<td>Cl</td>
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<td>V</td>
<td>Cr</td>
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<td>Sr</td>
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<td>Zr</td>
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<td>Ba</td>
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<td>Os</td>
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<td>Ra</td>
<td>Ac</td>
<td>Th</td>
<td>Pa</td>
<td>U</td>
<td>Np</td>
<td>Pu</td>
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<td>7</td>
<td>Ce</td>
<td>Pr</td>
<td>Nd</td>
<td>Pm</td>
<td>Sm</td>
<td>Eu</td>
<td>Gd</td>
<td>Tb</td>
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<tr>
<td></td>
<td>Dy</td>
<td>Ho</td>
<td>Er</td>
<td>Tm</td>
<td>Yb</td>
<td>Lu</td>
<td>Th</td>
<td>Pa</td>
</tr>
</tbody>
</table>

- **Alkali Met.**
- **Metal**
- **Non-Metal**
- **Trans. Met.**
- **Halogen**
- **Noble Gas**
- **Actinide**
- **Chalcogens**

**Lanthanide Series**
- Ce 140.1
- Pr 140.9
- Nd 144.2
- Pm 145

**Actinide Series**
- Th 232.0
- Pa 231.0
- U 238.0
- Np 237.0

*Swerea MEFOS*
ΔH, reaction or formation energy
ΔS, disorder, spontaneity

Monday

Friday

ΔS > 0
\[ \Delta G = \Delta H - \Delta S \]

- \( \Delta G < 0 \), possible
- \( \Delta G > 0 \), not possible
Selectivity

Ca + 1/2O2 = CaO, $\Delta G_1 < 0$

Fe + 1/2O2 = FeO, $\Delta G_2 < 0$

$\Delta G_1 << \Delta G_2$
The lower the line, the more stable oxide.

The slope changes with phase change.

FeO is only stable at higher temperatures.
Activity

Once impurity elements are dissolved in the metal the activity of that will be low
Metallurgical processes for recycling

A: CaO, SiO2, Al2O3, MgO
B: NiO, FeO, MnO, V2O3, Cr2O3, P2O5, Cu, Co, Mo
C: ZnO, PbO, Na, K, Cl, Cd, Hg
D: C-H-O, plastics/textile/fluff
What is scrap?

- **Scrap**
- Used steel products, i.e. Fe with alloys
- Shredded scrap is a complex material containing
  - switches, cables
  - coatings, e.g. organic or metallic
- Coatings may result in hazardous and problematic compounds in exhaust gas
Conventional EAF smelting of steel scrap
Scrap-based process metallurgy
Recyclability of tramp elements in scrap

- Mo, Ni, Sn, Cu: Vaporizing elements
- Pb, Zn, Sb: Controllable elements by slag forming
- Nb, B, Ti, Zr, V, Al, Si: Remaining ratio (%)
Expected distribution of the radioactive elements in scrap

Co, Ag
Mo, Ni, Sn, Cu

Pb
Zn
Sb
Controllable elements by slag forming

Mn
Cr

Cs, Zn

 Nb, B, Ti, Zr, V, Al, Si
Sr, U, Pu, Am
# Nuclide distribution from steel scrape

<table>
<thead>
<tr>
<th>Nuclide</th>
<th>Steel (%)</th>
<th>Slag (%)</th>
<th>Dust (%)</th>
<th>Other (%)</th>
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<tbody>
<tr>
<td>Mn-54</td>
<td>24-100</td>
<td>1-75</td>
<td>0-5</td>
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<tr>
<td>Co-60</td>
<td>20-100</td>
<td>0-1</td>
<td>0-80</td>
<td>0</td>
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<tr>
<td>Zn-65</td>
<td>0-20</td>
<td>0-1</td>
<td>80-100</td>
<td>0</td>
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<tr>
<td>Sr-90</td>
<td>0-20</td>
<td>95-100</td>
<td>0-10</td>
<td>0</td>
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<tr>
<td>Ag-108m</td>
<td>75-100</td>
<td>0-1</td>
<td>0-25</td>
<td>1 (bottom)</td>
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<tr>
<td>Sb-125</td>
<td>60-100</td>
<td>0-20</td>
<td>10-40</td>
<td>0</td>
</tr>
<tr>
<td>Cs-137</td>
<td>0</td>
<td>0-5</td>
<td>95-100</td>
<td>0</td>
</tr>
<tr>
<td>U</td>
<td>0-1</td>
<td>95-100</td>
<td>0-5</td>
<td>0</td>
</tr>
<tr>
<td>Pu</td>
<td>0-1</td>
<td>95-100</td>
<td>0-5</td>
<td>0</td>
</tr>
<tr>
<td>Am-241</td>
<td>0-1</td>
<td>95-100</td>
<td>0-5</td>
<td>0</td>
</tr>
</tbody>
</table>
Scrap preheating and surface cleaning

Fuel, slag additives → Oxygen → Combustion → Hot gas → Temp adjustment → Hot gas → Return gas → Scrap preheating → Hot gas → Cold scrap → Exhaust → Gas cleaning

Slag → Hot scrap → Melting → Zn recovery
Conclusions

• Thermodynamics applied for the conventional steel scrap can also be applied for cleaning, smelting and refining of radioactive scrap
• The operational results confirm the validity of the thermodynamic principle. Agreement between observation of nuclide distribution and thermodynamic data.
  • Am, U, Pu will go to the slag phase
  • Zn will evaporate
  • Co-60, and all other radioactive cobalt isotopes, will stay in the molten metal when melted under standard conditions in air

We should use thermodynamic principle to guide our future innovation in this field
Thank you and questions?