**Abstract**

We measured the transition energies of the 1s→2p \( \text{K} \alpha \) transitions in Al\(^{11+}\) through Al\(^{15+}\). The aluminum ions were created and trapped using the LLNL's Electron Beam Ion Trap (EBIT). Once created and trapped, upper levels were collisionally excited by electrons in EBIT's electron beam. X-ray emission following radiative decay of excited levels was detected using the EBIT Calorimeter Spectrometer (ECS). We have measured the centroids of the strongest line to an accuracy of less than 1 eV. These results will be used to properly identify line emission from celestial x-ray sources, such as elliptical galaxy NGC 4472 and black hole candidate Cyg X1, where x-ray emission from aluminum has been hypothesized. These results will be especially useful after the upcoming launch of the AstroH X-ray observatory in late 2015. Owing to its large collection area and relatively high resolving power, the Soft X-ray Spectrometer (SXS) calorimeter instrument on board Astro-H will, for the first time, make it possible to detect emission from highly charged aluminum ions, regardless of its low cosmic abundance.

**Method & Results**

<table>
<thead>
<tr>
<th>Label</th>
<th>Ion</th>
<th>Transition</th>
<th>( E ) (eV)</th>
<th>( E^* ) (eV)</th>
<th>( \Delta E ) (eV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>F-like Al(^{11+})</td>
<td>1s2(2p^2) S(<em>2^0) - 1s2(2p^2) P(</em>{1/2})</td>
<td>1499.66</td>
<td>1487.36</td>
<td>2.3</td>
</tr>
<tr>
<td>1</td>
<td>O-like Al(^{11+})</td>
<td>1s2(2p^2) P(<em>{1/2}) - 1s2(2p^2) D(</em>{3/2})</td>
<td>1498.84</td>
<td>1500.34</td>
<td>-1.5</td>
</tr>
<tr>
<td>2</td>
<td>N-like Al(^{11+})</td>
<td>1s2(2p^2) P(<em>{3/2}) - 1s2(2p^2) D(</em>{5/2})</td>
<td>1513.85</td>
<td>1513.47</td>
<td>0.38</td>
</tr>
<tr>
<td>3</td>
<td>C-like Al(^{11+})</td>
<td>1s(3)2(2p^2) (P(<em>{3/2}) - 1s2(2p^2) P(</em>{1/2})</td>
<td>1529.35</td>
<td>1529.43</td>
<td>0.08</td>
</tr>
<tr>
<td>4</td>
<td>B-like Al(^{11+})</td>
<td>1s2(2p^2) (P(<em>{1/2}) - 1s2(2p^2) P(</em>{3/2})</td>
<td>1545.55</td>
<td>1546.12</td>
<td>0.57</td>
</tr>
<tr>
<td>5</td>
<td>Be-like Al(^{11+})</td>
<td>1s2(2p^2) P(_{3/2}) - 1s2(2p^2) S(_2^0)</td>
<td>1564.27</td>
<td>1563.38</td>
<td>0.93</td>
</tr>
<tr>
<td>6</td>
<td>He-like Al(^{11+})</td>
<td>1s2(2s^2) S(_2^0) - 1s2(2s^2) S(_2^0)</td>
<td>1574.5</td>
<td>1574.64</td>
<td>0.14</td>
</tr>
<tr>
<td>7</td>
<td>Li-like Al(^{11+})</td>
<td>1s(3)2(2s^2) (P(<em>{3/2}) - 1s2(2s^2) P(</em>{1/2})</td>
<td>1580.02</td>
<td>1579.73</td>
<td>0.29</td>
</tr>
<tr>
<td>8</td>
<td>He-like Al(^{15+})</td>
<td>1s2(2p^2) P(_{1/2}) - 1s2(2s^2) S(_2^0)</td>
<td>1598.35</td>
<td>1597.99</td>
<td>0.36</td>
</tr>
</tbody>
</table>

\( E^* \) = measured energy

*Theoretical numbers in column four in the table are from Palmeri et al. 2011

**Summary**

- We have measured the transition energy of 1s→2p transitions in highly charged Al\(^{11+}\) through Al\(^{15+}\).
- These results will be used to benchmark highly sophisticated atomic physics codes used to interpret spectra from celestial sources.
- Accurate rest wavelengths will be used to determine doppler shifts of lines measured with the SXS on Astro-H.

**References**


This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under contract DE-AC52-07NA27344.

**EBIT Calorimeter Spectrometer (ECS)**

- Photons incident on the ECS HgTe absorber material raise the absorber's temperature.
- Temperature rise depends on the energy of the incident photon.
- The ECS is sensitive enough to measure the temperature rise from a single incident photon.

**Method & Results**

**Calibration Spectrum**

The energy scale of the ECS is calibrated using the well known energies of X-rays emitted from hydrogenic and helium-like magnesium, aluminum, and silicon.

**Summary**

- We have measured the transition energy of 1s→2p transitions in highly charged Al\(^{11+}\) through Al\(^{15+}\).
- These results will be used to benchmark highly sophisticated atomic physics codes used to interpret spectra from celestial sources.
- Accurate rest wavelengths will be used to determine doppler shifts of lines measured with the SXS on Astro-H.

**References**


This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under contract DE-AC52-07NA27344.