Measuring K-shell Transitions in L-shell Ions of Aluminum Using LLNL EBIT

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EBIT

EBIT is used to produce and trap highly charged ions.

How are ions trapped?

- Radially by the space charge of the electron beam
- Axially using three electrodes set to different electric potentials

How is X-ray Emission produced?

- Direct excitation following electron collision
- Inner shell ionization following electron collision

EBIT	Close-up of EBIT trap region

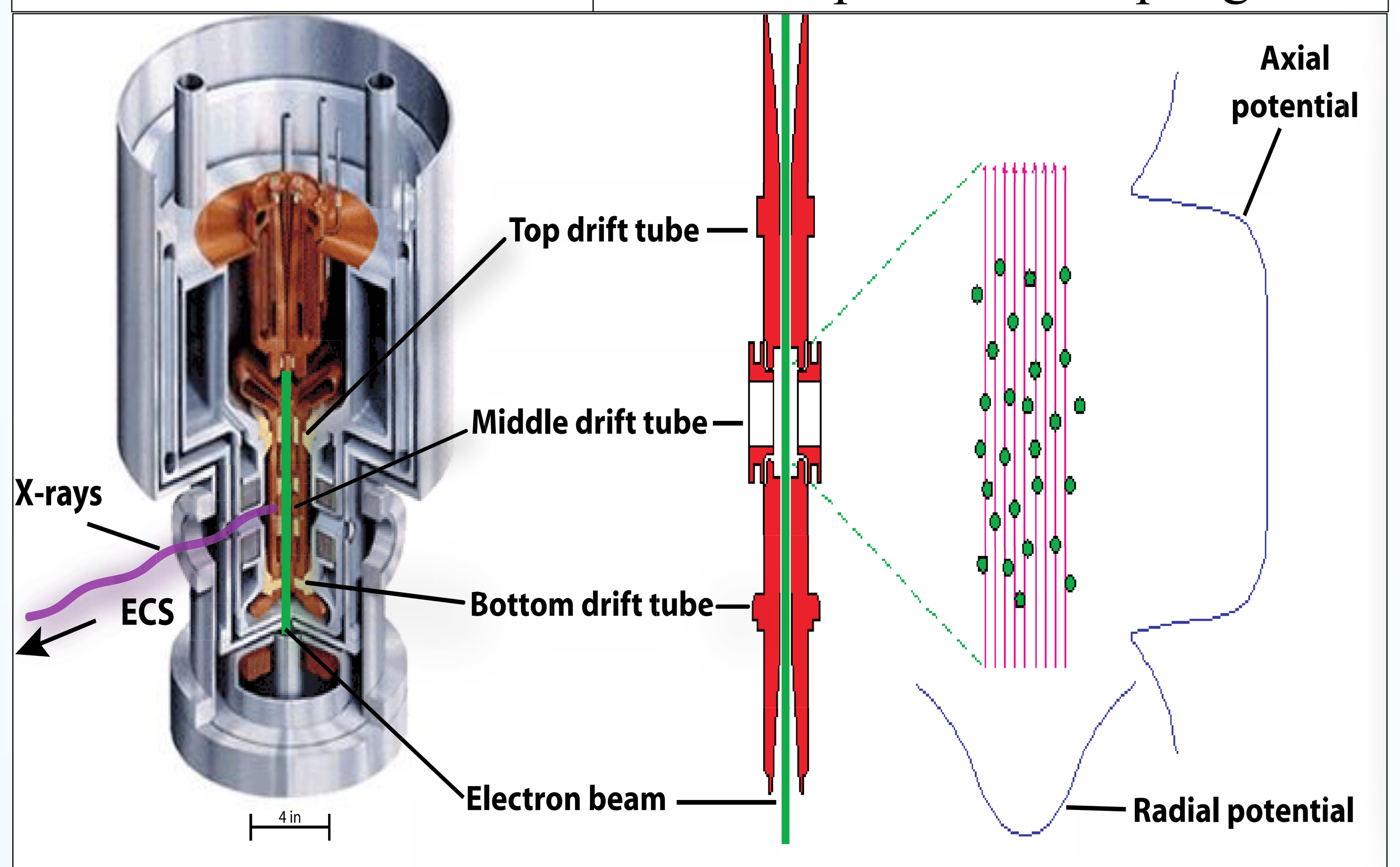


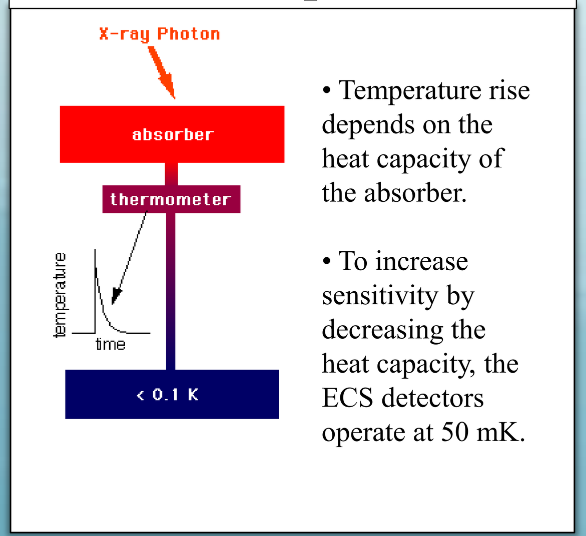
Figure 2: Diagram of the EBIT. Electrons are shown in green

EBIT Calorimeter Spectrometer (ECS)

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

Photograph of ECS at EBIT

Cartoon of Photon Absorption

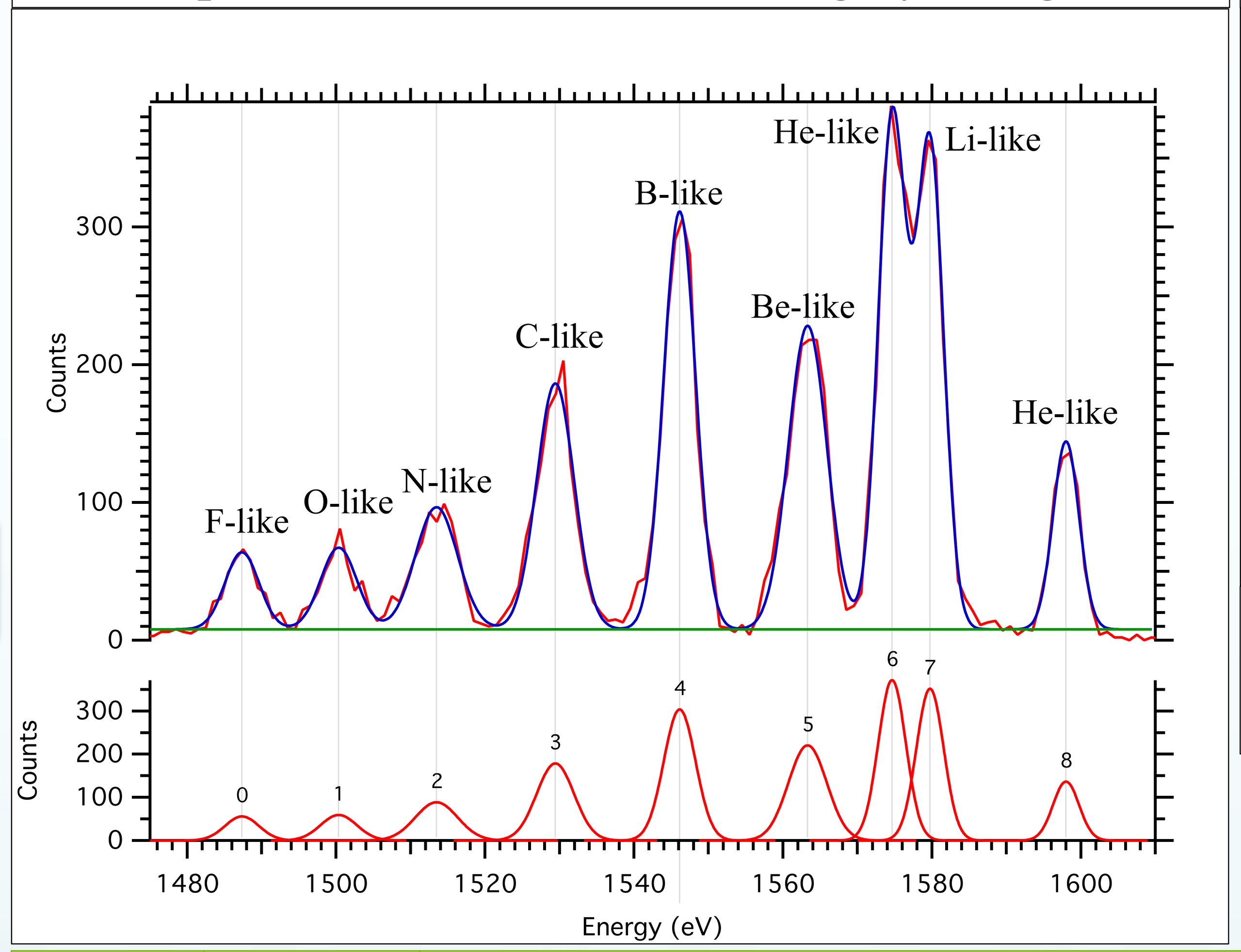


Abstract

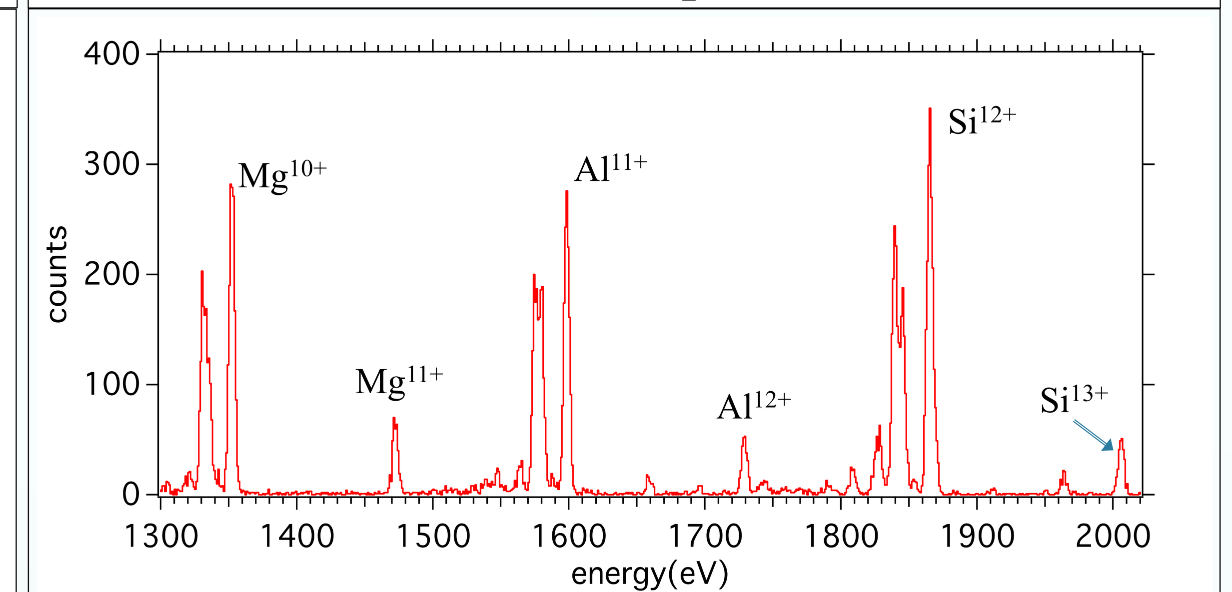
We measured the transition energies of the 1s-2p Kα transitions in Al^{4+} through Al^{11+}. The aluminum ions were created and trapped using the LLNL's Electron Beam Ion Trap (EBIT). Once created and trapped, upper levels were collisionally excited by electrons in EBIT's electron beam. X-ray emission following radiative decay of excited levels was detected using the EBIT Calorimeter Spectrometer (ECS). We have measured the centroids of the strongest lines 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

ECS spectrum of emission from highly charged Al



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

Label	Ion	Transition	E (eV)	E^m (eV)	Δ E (eV)	Uncertainty
0	F-like Al^{4+}	$1s2s^22p^6\ ^2S_{1/2} - 1s^22s^22p^5\ ^2P^o_{3/2}$	1489.66	1487.36	2.3	±.78
1	O-like Al^{5+}	$1s2s^22p^5\ ^1P^o_1 - 1s^22s^22p^4\ ^1D_2$	1498.84	1500.34	1.5	±.78
2	N-like Al^{6+}	$1s2s^22p^4\ ^2P_{3/2} - 1s^22s^22p^3\ ^2D^o_{5/2}$	1513.85	1513.47	.38	±.70
3	C-like Al^{7+}	$1s(^2S)2s2p^4(^2P)\ ^1P_1 - 1s^22s2p^3\ ^1D^o_2$	1529.35	1529.43	.08	±.59
4	B-like Al^{8+}	$1s2s^22p^2\ ^2P_{3/2} - 1s^22s2p^2\ ^4P_{1/2}$	1545.55	1546.12	.57	±.55
5	Be-like Al^{9+}	$1s2s^22p\ ^1P^o_1 - 1s^22s^2\ ^1S_0$	1564.27	1563.30	.93	±.58
6	He-like-Al^{11+}	$1s2s\ ^3S_1 - 1s^2\ ^1S_0$	1574.5	1574.64	.14	±.58
7	Li-like Al^{10+}	$1s(^2S)2s2p(^3P^o)\ ^2P^o_{3/2} - 1s^22s\ ^2S_{1/2}$	1580.02	1579.73	.29	±.59
8	He-like Al^{11+}	$1s2p\ ^1P_1 - 1s^2\ ^1S_0$	1598.35	1597.99	.36	±.60

*E^m = measured energy
*Theoretical numbers in column four in the table are from Palmeri et.al 2011

Astro-H

ASTRO-H scheduled to launch in 2015, carries several instruments to provide imaging and spectra across a large energy range. The SXS is the primary instrument.

5 Soft X-ray Spectrometer (SXS)

SXS is a detector that is cooled to an extremely low absolute temperature of 50mK, only fractions of a degree above absolute zero. With its energy resolution it will measure the dynamics of X-ray hot gas to unprecedented accuracy. Astro-H will take the world's first high resolution, high throughput X-ray spectrum of diffuse extended celestial sources.

Summary

- We have measured the transition energy of 1s-2p transitions in highly charged Al^{4+} through Al^{11+}.
- 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

Palmeri, P. Quinet, C. Mendoa, M.A. Bautista, J. Garcia, M.C. Witthoeft, and T. R. Kallman, 2011, A&A 525, A59.

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

LLNL-POST-658396