Introduction:

While photoionization of helium has been studied thoroughly, beryllium (Be²⁺), the next helium-like atom in the periodic table, has been investigated only marginally by comparison. Double excitations in the Be²⁺ valence-shell region have been studied experimentally as well as theoretically in the past. In these experiments [1,2] vacuum sparks were used to photoexcite and -ionize Be atoms and absorption spectra were recorded on high-sensitive film. In general, for atomic photoionization processes above the first ionization limit, autoionization becomes possible by interaction with one or more single-ionization continua. This leads to an asymmetric resonance profile in the single-ionization cross section. A theoretical description of this process was introduced by Fano [8] and refined later by Shore [14] and Stancil [15]. Since autoionization is a consequence of electron correlation, a measurement of the resonance profile for comparison with theory can provide important information towards our understanding of how electron correlations affect a simple system. Since the 1s electrons do not actively participate in the autoionization process, Be appears to be a system only slightly more complicated than He. However, it is very different from He insofar as the series of autoionization resonances starts immediately above the first ionization threshold (see Fig. 3). Another difference to He is that the Be 2p₂ₙ lines are much broader due to a strong coupling to a rather weak continuum.

Experiment:

The experiment was performed at the Synchrotron Radiation Center (SRC). Ion-yield measurements were carried out at the 4-m normal incidence monochromator (NIM) beam line [9]. Photons monochromatized by a 1200 lines/mm Al-MgF2 grating entered the experimental chamber through a glass capillary and impacted the Be vapor emerging from a resistively heated oven (see below). The temperature of the oven was typically 1150°C. The crucible was electrically biased to prevent thermal electrons from reaching the interaction region. The ions created were extracted by a pulsed electric field across the interaction region, accelerated into a drift tube, and detected by a Z-stack microchannel-plate detector (see above).

By measuring the ions' flight time we obtained a time-of-flight (TOF) ion-yield spectrum. We set a time window across the Be⁺ peaks and, using a rasterer, measured the count rate while scanning the photon energy. The photon flux was measured separately with an XUV100 silicon photodiode which has a known quantum efficiency. The resulting flux curve was normalized according to the electron beam current in the storage ring, which was recorded along with the Be⁺ data. We also took a TOF spectrum before each photon energy scan to determine the background. The Be⁺ scatters were background corrected and normalized to the photon flux before further analysis. Further details of the experimental setup can be found elsewhere [10].

Conclusions:

In summary, we have measured the Be⁺ photoionization yield in the region of the 2pₙ (n=1-12) double excitations and applied the Fano formula to the 2pₙ resonance energies. The positions of the resonances are in good agreement with a previous experiment [2] and theoretical calculations [4,6]. From the energy positions we derive a quantum defect 6-0.61(1) for the n= series and 6-0.06(15) for the n=5 series. The resonance widths multiplied by (n²) with n² as the effective quantum number remain constant and agree well with the predicted widths [3,6]. The Fano parameter for the 2pₙ (n≤6) resonances are approximately 0.54, except for the 2p₅ resonance, which has a clearly lower g value of 0.95(6). Overall, the Fano parameters calculations of Tully et al. [4] and Kim et al. [6] are able to model autoionization resonances of a closed-shell atom, such as Be+, very well. The hyperbolic method employed by Greene [3] also predicts the shape of the resonances fairly well, but does not calculate the right energy positions.

References


Acknowledgments

This work was supported by NSF Grant No. 99-0638. The SRC is operated under NSF Grant No. DMR-0084040.