Radiative Recombination Studies of Highly Charged Ions with Free Electrons in the ESR Storage Ring at GSI (Darmstadt)

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Recombination processes of highly charged ions are fundamental for the understanding of astrophysical and fusion plasmas and provide useful information for accelerator physics. At very low relative energies between ions and electrons an unexpected high rate of radiative recombination (RR) was found [1, 2] exceeding theoretical predictions [3] by more than two orders of magnitude. Recent measurements [4] have shown that very high enhancement factors may be due to the presence of dielectronic recombination (DR) resonances near zero relative energy. However, the enhancement by a factor of 5 and larger was also observed for bare ions where the DR process cannot occur.

In order to study RR of a bare heavy ion the 295.3 MeV/u Bi^{83+} ions injected into the ESR were merged with the electron cooler beam. Recombination processes occurred along the 2.5 m long common trajectory of electron and ion beams. Recombined Bi^{82+} ions were counted with a scintillation detector. Fig. 1 shows the recombination rate as a function of relative energy between electrons and ions.

The calculated RR curve shown in the figure has been obtained using a maximum principal quantum number $n_{max} = 116$ and electron temperatures $kT_{\parallel} = 0.1$ meV and $kT_{\perp} = 120$ meV. Good agreement has been found for relative energies above 15 meV. At lower energies experimental data exceed calculated values. The maximum rate coefficient exceeds the theoretical rate at $E_{rel} = 0$ eV by a factor of 5.2.

The enhancement factor has been investigated as a function of other cooler parameters, as electron density, magnetic guiding field and angle between the two interacting beams. The magnetic guiding field dependence, showing an oscillatory character observed also in the previous experiments in GSI, revealed an interesting correlation between the enhancement factor and the fitted value of transverse electron temperature (being also a measure of the electron beam quality). This is presented in Fig. 2. However, explanation of the physical origin of this dependence needs further investigations.

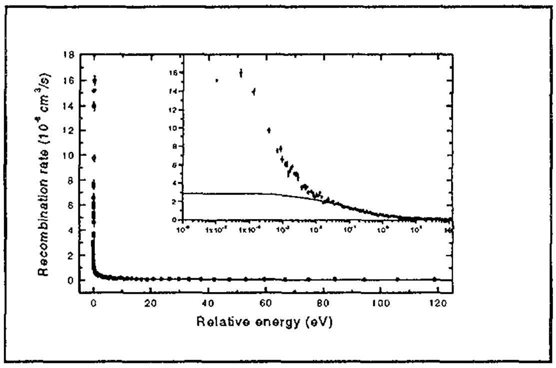

Fig. 1. Measured (circles) and calculated (solid line) recombination rate of Bi^{83+} plotted as a function of relative energy between electrons and ions.

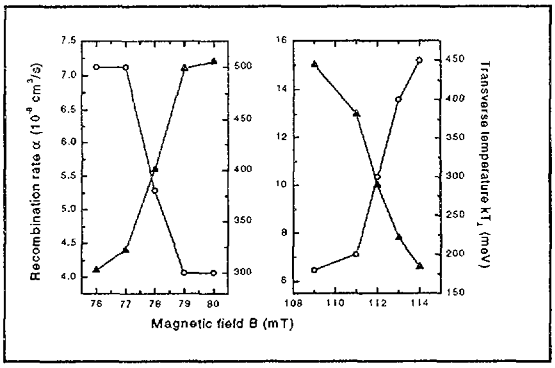

Fig. 2. Comparison of the measured maximum rate coefficients of Bi^{83+} (full triangles) for different magnetic fields and the transverse electron temperatures (open circles) inferred from fits to recombination spectra at energies beyond 0.1 eV.

References:

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3. H. Bethe and E. Salpeter, "Quantum Mechanics of One- and Two-Electron Systems " (Springer, Berlin 1957);
4. *e.g.* O. Uwira et al., Hyp. Interact. **108** (1997) 149.