XA0200416

Summary Report on Research Project 10237/R0: State selective charge transfer at low energies

Principal investigator: R. Hoekstra,
Participants: G. Lubinski, Z. Juhasz, J.W. Turkstra, D. Meyer, R. Morgenstern.

Within the Co-ordinated Research Project on "Charge exchange cross section data for fusion plasma studies" the main objective of the KVI Atomic Physics group has been the production, assessment and recommendation of fundamental atomic physics data for fusion plasma research. The emphasis has been on charge transfer reactions between multicharged ions (A^{q+}) and neutrals (B), at energies of divertor and scrape-off-layer relevance. The electron transfer processes are schematically given by:

$$A^{q+} + B \rightarrow A^{(q-1)+}(nl) + B^{+}$$

with nl the principal and angular momentum quantum numbers of the state into which the donor electron is captured. Subsequentely to this reaction the $A^{(q-1)+}(nl)$ ion decays under photon emission, the process on which both passive and active charge exchange recombination spectroscopy (CXR) diagnostics is based.

For the diagnostics and modelling of divertor and edge-plasma regions, cross sections for collision energies well below 1 keV/amu are needed. We redesigned, reconstructed and took into operation a set-up to perform experiments in this yet unexplored low-energy regime. Ion beams were successfully decelerated down to energies as low as a few eV/amu.
First experiments were performed with He^{2+} and and He-like C^{4+}, N^{5+} and O^{6+} ions colliding on molecular hydrogen. These systems were chosen because, except for O^{6+}, there exist recent, elaborate quantum mechanical calculations for comparison. For He^{2+}, in accordance with theory we find that at low energies two-electron capture dominates fully over one-electron capture. But, the absolute values differ by a factor of 3 and in addition the final state distribution which determines the photon emission is distinctly different from theory. For N^{5+}, the experimental cross sections are much larger, more than an order of magnitude, than predicted by theory. Below 20 eV/amu, the dominant capture channel $N^{4+}(3s)$ is a factor of 1000 more efficient than predicted by theory. For C^{4+} ions the differences between theories and experiment are smaller but still considerable.

Altogether, all this seems to imply that low-energy charge-transfer calculations need to be considerably improved before they can be considered as a reliable basis for modelling and diagnostics of the scrape-off-layer and divertor regions in fusion plasma reactors.

On the database and modelling side work has been done in collaboration with the group of Summers (University of Strathclyde and JET Joint Undertaking) and the group of HP. Winter (Vienna) and J. Schweinzer (Garching). For Li beam based diagnostics, we have given support to the final data sets for diagnostics as prepared by the Vienna-Garching collaboration. The new assessments (Summers and coworkers, including the KVI group) of neutral beam stopping and excitation data led for the first time to agreement on an absolute scale of observed and calculated neutral beam densities and beam emission intensities.

Output (partly) related to the CRP on: "Charge exchange cross section data for fusion plasma studies"

Electron and neutral interactions with impurities in divertor plasmas
H.P. Summers, H. Anderson, N.R. Badnell, F.W. Bliek, M. Brix, F.J. de Heer, R. Hoekstra, D.C. Griffin, L.D. Horton, C.F. Maggi, M.G. O'Mullane and M.S. Pindzola
Plasma Phys. Rep. **25** (1999) 15

Lithium excitation by slow H^+ and He^{2+} ions
J.W. Turkstra, D. Meyer, R. Hoekstra, R. Morgenstern and J. Schweinzer
Phys. Rev. A. **60** (1999) 4627

Database for inelastic collisions of lithium atoms with electrons, protons and multiply charged ions

J. Schweinzer, R. Brandenburg, I. Bray, R. Hoekstra, F. Aumayr, R.K. Janev and HP. Winter
At. Nucl. Data. Tabl. **72** (1999) 239

Electron capture by slow multicharged ions from atoms, molecules and surfaces
R. Hoekstra and R. Morgenstern
In: *Highly Charged Ion Physics* (ed. J. Gillaspy, Nova publishers, 1999)

Neutral beam stopping and emission in fusion plasmas I: Deuterium beams
H. Anderson, M. von Hellermann, R. Hoekstra, L.D. Horton, A.C. Howman, R.W.T. Konig, R. Martin, R.E. Olson and H.P. Summers
Plasma Phys. Controll. Fusion. **42**, 781 (2000)

Molecular fragmentation by slow highly charged ion impact
R.D. DuBois, T. Schlathölter, O. Hadjar, R. Hoekstra, R. Morgenstern, C.M. Doudna, C.R. Feeler, R.E. Olson
EuroPhys. Lett. **49**, 41 (2000)

State selective electron-capture cross section measurements for low-energy collisions of He-like ions on H_2
G. Lubinski, Z. Juhász, R. Morgenstern, R. Hoekstra
J. Phys. B: At. Mol. Opt. Phys. **33,** 5275 (2000)

Low-energy state-selective charge transfer by multiply charged ions
G. Lubinski, Z. Juhász, R. Morgenstern and R. Hoekstra,
Phys. Rev. Lett. **86**, 616 (2001)