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Proposal for experiments at Tandem accelerator, Department of Nuclear Physics, IFIN-HH

Inner (K- and L-) shell ionization and quasi-molecular mechanisms of electron promotion and ionization

Motivation

Although the coulomb interaction, responsible for the atomic interactions is very good known, detailed understanding of inner-shell electron ionization / transfer processes is difficult due to many-body character, and therefore continues to be of interest. The collision products, like X-rays and/or Auger electrons, secondary electrons and recoil ions, could be measured and differential measurements (e.g. in coincidence with the emergent ions) could give us more detailed information on the excitation mechanisms (see e.g. [1] for collisions in the K-L level matching region). Even integral measurements could give us interesting results involving inner-shell electron ionization / transfer processes. In this case, information about the associated multiple ionization in the outer shells could be obtained from X-ray or Auger electron spectra analysis [2].

The X-ray excitation in the light ion - atom collisions has been intensively studied in the last decades in order to develop and test theoretical approaches, as well as to build a database of X-ray production cross sections for applications, like the particle induced X-ray emission (PIXE). A rather good understanding of X-ray production by light ion impact (protons, alpha particles etc.) has been obtained (see e.g. [3,4]); however, there are much less data for heavier ions. Direct ionization of the inner- (K- and L-) shells by light ions can be reasonably described by first-order treatments based on non-relativistic plane wave Born (PWBA) and semiclassical (SCA) approximations. These theoretical approaches have been further extended to include higher order effects, like electron binding / polarization, as well as projectile Coulomb deflection or relativistic effects.

The inner-shell vacancy production in slow heavy-ion – atom collisions, in so called K-K, K-L etc. level matching regions, is dominated by quasimolecular excitation mechanisms. Thus, integral and differential measurements in collision systems in the K-L level matching region give us information about the collision processes: vacancy production in 3dσ molecular orbital (MO) and vacancy sharing between 3dσ MO and other MOs [1].

The first aim of the present proposal is to obtain new experimental evidence for the quasi-molecular mechanisms of electron promotion and excitation (ionization) in the K-L level matching region, by using integral as well as differential after the impact parameter measurements.

Another aim of integral cross sections measurements is the application of heavier ions to analytical work (PIXE). Using heavy ions PIXE needs to supplement the inner-shell ionization cross section data, for many projectiles, target elements or impact energies. New data are also necessary to overcome some standardization difficulties, due to, for ex., the multiple ionization effects, which induce modifications in the X-ray energies and relative yields.

Proposal

For the present beam, we propose integral measurements of ionization cross sections of Pt by projectile ^{55}Mn, in dependence of collision energy, as well as test measurements of X-ray – X-ray and X-ray – scattered particles coincidences.

These measurements will provide new insights into the quasi-molecular mechanisms of vacancy production and sharing in the K-L level matching region, by comparing with available theoretical calculations for direct ionization of the 3dσ MO and vacancy sharing.

By using the energy and yield shifts measurements, outer-shell multiple ionization probabilities could be estimated and interpreted in terms of first order models (like the geometrical model).

Experiment

Integral measurements: the collimated ion beams of ^{55}Mn charge state and energy selected by a 90^0 analyzing magnet in the energy range of 0.25-2.0 MeV/u, will bombard a thin selfsupported Pt target, tilted at 45^0 to the beam direction. The emitted X-ray spectra will be measured with a Si(Li) or Ge HP detector, placed at 90^0 to the beam direction. The scattered projectiles are measured by using a thin plastic scintillator foil (110 μm thichness) placed at 90^0, or at a forward angle. The efficiency and the solid angle of the X-ray and particle detectors will be measured using calibrated X-ray and alpha radioactive sources (^{241}Am). *The needed beam time*: because an excitation function of about 3 hours/energy at about 20 energies is necessary, and taking into account the time for the beam and measuring conditions tuning, we appreciate the needed beam time for these measurements of *4 days*.

Differential measurements: for the same collision system as before, *2 days* of tests of coincidence measurements X-ray – X-ray and X-ray – scattered projectile are proposed. Two X-ray detectors placed at 90^0 to the beam direction and a position-sensitive particle detector placed at forward angles will be used.

The total needed beam time: 4+2 days.

References

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