ATOMIC COLLISIONS RESEARCH WITH EXCITED ATOMIC SPECIES

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Measurements and calculations of fundamental atomic collision and spectroscopic properties such as collision cross sections, reaction rates, transition probabilities etc. underpin the understanding and operation of many plasma and gas-discharge-based devices and phenomena, for example plasma processing and deposition. In almost all cases the complex series of reactions which sustains the discharge or plasma, or produces the reactive species of interest, has a precursor electron impact excitation, attachment, dissociation or ionization event. These processes have been extensively studied in a wide range of atomic and molecular species and an impressive data base of collision cross sections and reaction rates now exists. However, most of these measurements are for collisions with stable atomic or molecular species which are initially in their ground electronic state. Relatively little information is available for scattering from excited states or for scattering from unstable molecular radicals. Examples of such species would be metastable excited rare gases, which are often used as buffer gases, or CF_2 radicals formed by electron impact dissociation in a CF_4 plasma processing discharge. We are interested in developing experimental techniques which will enable the quantitative study of such exotic atomic and molecular species. In this talk I would like to outline one such facility which is being used for studies of collisions with metastable He(2^3S) atoms.

Metastable He(2^3S) is the longest lived, low lying atomic state, with a lifetime which has been calculated at 8000 seconds. As such it can exist in relatively large equilibrium populations in low pressure gas discharges and, as it also possesses a large amount of internal energy (19.8 eV), collisions with it can result in the transfer of substantial amounts of energy and have a significant effect on the behaviour of such a discharge. Collision studies of these excited atoms are few as they are difficult to produce in a controlled, high density beam. Typical gas discharge or charge exchange sources which have been used for these studies produce at most about 10^7 atoms.cm^{-3} compared with number densities of 10^{12}-10^{13} atoms.cm^{-3} which are used for conventional scattering experiments with ground state targets. In addition, as most production methods involve a discharge source, they have the disadvantage of also producing high background fluxes of electrons, ions, VUV photons, and RF noise which make low energy scattering experiments very difficult. As a result signal levels, and signal to background conditions, are generally quite poor.

At the ANU we have developed a "bright" beam of metastable helium (2^3S) atoms and a magneto-optical trap (MOT) for He(2^3S) to facilitate a broad range of experiments in electron scattering, excited atom-excited atom scattering, atom optics, atom lithography and fundamental spectroscopy. This facility draws on laser cooling and trapping techniques which have been developed over the past 15 years or so and which have provided a quiet revolution in many aspects of atomic physics. In the present apparatus, the beam is produced from a liquid nitrogen cooled, DC discharge and a range of laser cooling techniques (using the 2^3S-2^3P transition at 1083 nm) are used to collect a large fraction of the excited atoms that diverge from the source aperture.

The atoms are then collimated, slowed and focused to a point some four metres from the source. The resulting beam is slow (v = 100-200 $m.s^{-1}$), monochromatic (Δv = 1-5 $m.s^{-1}$), dense ($N \sim 10^8$ $atoms.cm^{-3}$) and in a region of very low background.

This bright beam can be used for experiments and also to load the MOT for helium, which is located at the end of the beam line. With this facility a range of atomic physics experiments are being pursued:

- low energy electron collisions
- recoil atom spectroscopy
- excited atom-excited atom collisions (including highly excited states)
- atom optics
- atom lithography
- metastable atom spectroscopy

Details of the beam line performance and the first experiments from the apparatus will be presented.