Absolute excitation-emission cross section of electron induced argon excitation

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Synopsis The electron impact excitation-emission cross section of argon $4P^2[1/2] \rightarrow 4S^2[1/2]°$ [1] was experimentally investigated in the electron energy range 5eV – 100eV. The absolute value of the cross section was calibrated by comparison with the known cross section for the helium transition He $3^1S \rightarrow 2^1P^0$ [2].

The argon deexcitation $4P^2[1/2] \rightarrow 4S^2[1/2]°$ produces one of the strongest argon emission lines (750.39 nm) and the absolute value of the cross section for electron-atom reaction is often utilized in optical emission spectroscopy of electrical discharges. The cross section value was re-evaluated experiementaly in this work.

The experiment was conducted on Electron Induced Fluorescence (EIF) apparatus (described in detail in [3]) utilizing crossed beams of monochromatic electrons and atoms/molecules. The electron beam is formed by thermal emission from hairpin tungsten filament and subsequently it is energy filtered by trochoidal electron monochromator. For this experiment the electron energy resolution was set to ~200 meV (FWHM) and the electron current was in the range of 600 – 800 nA. Argon beam was created by effusion through a capillary. The background pressure in vacuum chamber was set to ~10^{-4} mbar to ensure single-collision conditions. Photons emitted from excited atoms were collected by an optical system, consisting of collimating optics, Jobin Yvon THR1500 Czerny-Turner monochromator and thermoelectrically cooled Hamamatsu R3869 photomultiplier working in photon counting mode with background noise averaging at 3.6 cps, primarily due to photomultiplier thermal noise.

The narrow spectral range around the expected argon line was measured at several different electron energies (25 eV, 50 eV and 100 eV) well above the excitation limit for the process in question at high optical resolution to ensure there are no other spectral lines present in the vicinity that might influence the measured cross section. Identical procedure was used to measure photon efficiency curve of the He 728.13 nm line. The pressure in the effusive capillary was kept constant for both measurements ensuring equal sample densities in the reaction region. Electron energy step was 0.5 eV before the excitation threshold, 0.1 eV around the threshold and cross section maximum and 1 eV for the rest of the curve.

Process of calculating the absolute cross section has multiple steps, as there are some properties of the experiment for which we have to make corrections, specifically pressure, electron current and spectral sensitivity corrections.

For the argon 4P2[1/2] → 4S2[1/2]° transition the main peak and broader secondary peak was observed. It is typical for cross sections with contribution of cascade processes from the higher excited states, in addition to direct excitation. This phenomenon can be observed also at the rising slope of the cross section, which exhibits multiple threshold structure. This will be a subject of further study using higher electron beam resolutions and also more complex numerical fits of the rising edge.

The values of the argon cross section were determined at electron energies 25 eV, 50 eV and 100 eV along with the value of excitation threshold. Experimental uncertainties were estimated by taking into account the statistical uncertainties of the measurements, pressure and current uncertainties and finally the uncertainty of helium reference cross section.

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