PHOTOIONIZATION IN GASES

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SUMMARY

This thesis describes the measurement of partial photoionization cross-sections for processes which lead to the formation of the ion in a particular quantum state. Partial cross-sections for oxygen, nitrogen and water vapour have been measured.

Previous determinations of photoionization cross-sections have been limited to measurements of the total cross-section for a multiplicity of processes corresponding to transitions to any one of a number of quantum states of the ion. Two examples of total cross-section measurements are presented in this thesis. Total cross-sections of molecular oxygen have been measured in the region from 1050 Å to 1250 Å. This region includes the wavelength of hydrogen Lyman-α, an important emission line in the solar spectrum. A double parallel plate ion chamber has been used to measure total photoionization cross-sections of nitric oxide in the region 1150 Å to 1350 Å. This chamber has also been used with argon to measure absolute beam intensities according to the method of Samson.

The partial photoionization cross-sections have been determined by recording the energy spectra of the photo-electrons. The spectrometer, which was of the

retarding potential type, consisted of three concentric cylindrical electrodes: a collimating electrode, an analysing grid, and an anode. A one-metre near normal incidence monochromator has been used with a slit width corresponding to a resolution of 10 Å. The monochromator has been equipped with a helium capillary discharge lamp powered by a condensed spark discharge.

Electron energy spectra have been recorded by differentiating the output of the electrometer which measured the electron current at the anode, and applying this signal and the retarding voltage to the Y and X axes respectively of an X-Y co-ordinate plotter. Smoothed spectra have been obtained by digitising the spectra and using the memory storage of a multichannel analyser to add several scans of the spectrum.

Interpretation of the spectra has been aided by a study of the spectra of argon and hydrogen, which contain a single line and a single band respectively in the range of wavelengths used. The peak in the argon spectrum had a width at half height of 0.4 eV under the best conditions.

Spectra have been obtained over a wavelength range from the threshold for the first excited state of the ion to 584 Å for oxygen, nitrogen and water vapour.

The relative area associated with each peak has been measured, and this information combined with the total photoionization cross-section data of Cook and Metzger to produce partial cross-sections.

The partial cross-sections of oxygen show the thresholds of the $b^4\Sigma_g$ and $a^4\Pi_u$ states of $O_2^{\ +}$; the $A^2\Pi_u$ and the $a^4\Pi_u$ states are not properly resolved. The continua are seen to have the form of a step function modified by competition between the continua, and by autoionizing processes. At wavelengths longer than the $a^4\Pi_u$ threshold the spectra have a large peak at low energy as well as the peak corresponding to the $^2\Pi_g$ ground state. It is suggested that fluorescence occurs from a highly excited level of O_2 before auto-ionization to the $X^2\Pi_g$ state of $O_2^{\ +}$.

The nitrogen results show the thresholds of the $B^2\Pi_u^{\ +}$ and $A^2\Pi_u$ states of $N_2^{\ +}$. All the continua have a maximum just below the threshold. The $B^2\Sigma_u^{\ +}$ continuum has a maximum value which is less than half the maximum values of the $A^2\Pi_u$ and $X^2\Sigma_g^{\ +}$ continua.

The water vapour results show the continua corresponding to the $^2B_1$ and $^2A_1$ levels of H_2O^+, and another corresponding to dissociative ionization. Thes continua have little structure, and the onset is more gradual than in the case of oxygen and nitrogen.

The partial photoionization cross-sections have been used in calculations of the energy distribution of primary photoelectrons in the ionosphere, and in calculations of the overhead intensities of various fluorescent band systems emitted in the ionosphere.