Intense Lyman-α Radiation from a Dense Neon - Hydrogen Mixture ◊

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It is well known that excitation of dense rare gase mixtures by ionizing particles can lead to very intense spontaneous emission and laser effect on specific optical transitions via gas kinetic processes [1]. Due to the large number of possible combinations there are still new effects to be discovered. Here we describe an observation which was first made during an experiment at the Tandem accelerator in which nominally pure Neon was excited by a 100 MeV ^{32}S-beam. The VUV spectrum showed an extremely intense emission on the 121.567nm n=2 to 1 Lyman-α line. The Lyman-α line is of fundamental [2] as well as practical interest e.g. for hygrometers [3] and photolithography. The effect was reproduced and studied in more detail using low energy (14keV) electron beam excitation as described in refs. [4,5]. Small amounts of about 1mbar Hydrogen were deliberately added to Neon at atmospheric pressure in these experiments.

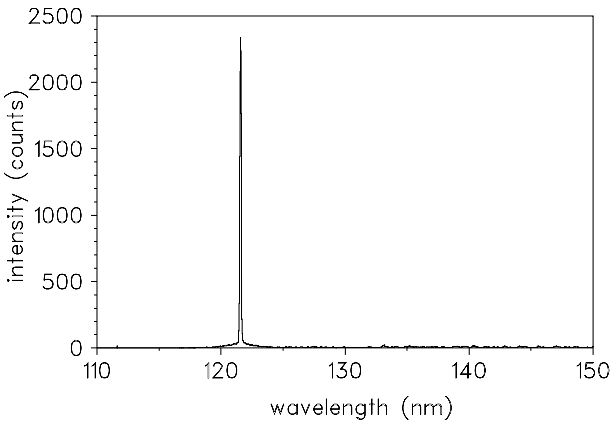

Fig. 1: Emission spectrum of a mixture of 1bar Ne and 1mbar H_2 excited by a 14keV electron beam. Similar spectra can be observed using heavy ion beam excitation.

A spectrum measured using 10μA, 14keV electron beam excitation is shown in fig. 1. A 10% conversion efficiency of beam power into Lyman-α-light could be determined. This line is essentially the only light emission observed over the entire wavelength region covered by our detection system from 110 to 800nm. In particular, emission from higher lying Hydrogen levels such as Balmer lines are completely absent. Lyman-α lamps described in the literature [6], so far, use Helium as a buffer gas. Using Helium instead of Neon in our system we find a 50 times weaker Lyman-α emission.

The gas kinetic processes leading to the observed effect have not been studied in detail up to now. There are, however, reasonable explanations for the high efficiency of Lyman-α- emission using dense Neon buffer gas and particle beam excitation: It is known that Neon excimer molecules form under these conditions [7] with strong emission on the first and second excimer continua between 75 and 90nm, corresponding to photon energies between 16.5 and 13.8eV. This is in coincidence with the sum of the dissociation energy of H_2 (4.481eV) and the excitation energy of a Hydrogen atom to the n=2 level (10.2eV). A resonant energy transfer between the decay of Ne_2^* molecules and dissociation plus excitation of Hydrogen may proceed via direct $Ne_2^*-H_2$ collisions or via photo emission and absorption, or both. Photodissociation of Hydrogen with fluorescence on the Lyman-α line is known from the literature [8].

Alternative kinetic processes finally leading to dissociation and excitation of Hydrogen may proceed via 3s Neon metastable atoms which are the precursors of the Neon excimer molecules. Comparing the 16.7eV excitation energy of this level with the potential energy diagram of H_2 and H_2^+ [9] one finds that a Hydrogen molecule could be ionized or excited into levels of the H(1s)+H*(2l) system in collisions with metastable Neon atoms. Molecular ions would have to undergo dissociative recombination for populating the H(1s)+H*(2l) levels. The observation that excitation of pure Hydrogen gas, or mixtures containing significantly more than 1% Hydrogen, radiate strongly on the molecular transitions suggests, however, that dissociative recombination should not be a dominant process.

A collisional transfer rate constant from Neon to Hydrogen of $3.6 \times 10^{-11} cm^3/s$ was determined from time spectra recorded on the Lyman-α line for various H_2 concentrations, a measurement which is independent of the transfer process. It is interesting to note that the Neon - Hydrogen energy transfer processes discussed above do not populate molecular levels H(1s)+H(n,l) with $n > 2$. This can explain the absence of Balmer transitions in the spectra.

Finally it should be noted that the electron beam excitation of the Neon - Hydrogen mixtures as described represents a compact, monochromatic VUV lamp emitting at 121.567nm with a high brightness of 10W per cm^2 entrance foil for the electron beam. The actual spectral width and shape of the line still needs to be studied. It is not yet clear whether the broad wings in fig. 1 are real or an instrumental artifact. Doppler broadening due to the excess energies involved in the energy transfer processes cannot account for the observed width. Stark- and saturation broadening will have to be considered for clarifying this issue.

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