PRESSURE DEPENDENCE OF RADIATIVE PROCESSES IN HELIUM

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The radiative processes in helium are studied. The role of atomic metastable states and of He_2^+ ions is determined.

Our purpose was to investigate the light emission by helium under conditions of low ion density and high pressure. These conditions can be obtained exciting helium gas by means of ionizing particles. The mechanism of the scintillation produced by α particles has been interpreted in terms of electron-ion recombination [1], formation of metastable molecules [2] or as impurities effects [3]. The apparatus used has been described in a previous paper [4]. The He was introduced in the gas chamber through a charcoal trap at liquid nitrogen temperature; other gases could be introduced, as controlled amounts of impurities, down to a minimum value of 2×10^{-4} Torr. An ^{241}Am α source was placed in the chamber. The apparatus, using a quartz window and a photomultiplier 6255 S, was sensitive from 2000 to 5700 Å. To detect the vacuum ultraviolet emission the internal surfaces of the chamber were coated by quaterphenyl as wavelength shifter. The pulse decay time of the u.v. radiation following an α particle emission was measured varying the He pressure. The pressure dependence above 1 atm is similar, but with higher absolute values, to that reported by Takahashi et al. [2]. We cannot explain this disagreement, moreover we find a change in the dependence at lower pressures, as shown in fig. 1. A decay time inversely proportional to the square of the pressure may be due, as suggested by Takahashi, to three-body collisions between a metastable He atom and two ground state atoms, according to the process: $He^m + He + He \rightarrow He_2 + He \rightarrow 3He + h\nu$. A dependence inversely proportional to the pressure, as that we find below 0.8 atm, may be instead caused by two-body collisions. This is an useful indication of the nature of He^m state. An important fraction of the energy expended in atomic excitation is stored in 2^1S state. However 2^3S state cannot be ignored, a priori, on account of excitation by

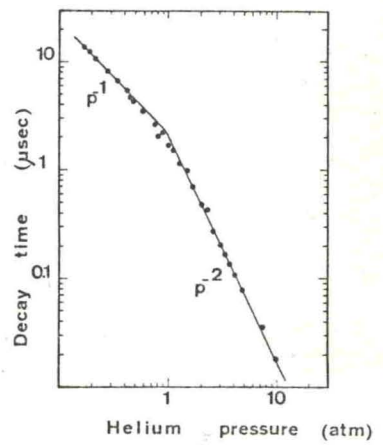

Fig. 1. Pressure dependence of the decay time of the vacuum ultra-violet radiation.

secondary electrons impacts or transfer processes involved in the depletion mechanism of n^1P states [3]. It is known [5] that three-body collisions are the dominant destruction process for 2^3S state above 10 Torr, so that a two-body mechanism prevailing up to 0.8 atm must be due to 2^1S state destruction. We can therefore obtain from the present data the two-body destruction cross section for this state, that results: $(8.5 \pm \pm 3) \times 10^{-20}$ cm^2. Phelps' data [5] may be fitted with a value of $(3 \div 4.5) \times 10^{-20}$; the overall error cannot be easily assigned, but we believe that the two data are in agreement within the accuracy of the two methods. The three-body destruction coefficient for 2^1S state results: $(6 \pm 2) \times 10^{-34}$ cm^2/atom^2 sec (at 300°K). From published data we can have only an upper limit of 6×10^{-33} [5].

A variety of impurities effects are reported in the literature, however are missing systematic data. We have studied the scintillation of He.

pressures ranging from 1 to 41 atm, in mixture with: N_2, O_2, CO, CO_2, NO, N_2O. The general trends are: a) the spectral distribution corresponds to vibrational bands of the molecular of the impurity, b) the amplitude of the light pulse is nearly independent from the impurity pressure until quenching values are reached, c) the amplitude is independent from the He pressure except for N_2 and CO mixtures, for which inversely proportional to this pressure, d) the decay time depends only from the partial pressure of the impurity, and is inversely proportional to this pressure (times of the order of 15 μsec at 10^{-3} Torr). At low concentrations the decay time due to impurity may be much longer of that of u.v. emission. This fact means that the energy source for impurity excitation is different from that of u.v. radiation. Are so excluded Pennig effects on impurity molecules produced by He atoms in metastable states. Taking also into account that the energy expended in ionization goes mainly in He_2^+ states, the most probable mechanism is the charge exchange: $He_2^+ + M \rightarrow 2He + M^{+v} \rightarrow 2He + M^+ + h\nu$; where M^{+v} is the molecular ion of the impurity in a vibrational excited state. This mechanism was suggested by Bennet [3] for He-N_2 mixture at 350 Torr. The maximum energy available for transfer in He_2^+, in its higher excited states is about 20.5 eV. A degree of vibrational excitation of He_2^+ ions, depending on the pressure, might show up through a variation of the yield of the impurity ions, when the energy required to produce the appropriate state is near to 20 eV. This is the case of the $B^2\Sigma^+$ states in N_2^+ and CO^+ (18.8 and 19.7 eV respectively). The cross sections for the charge exchange deduced from the time dependence (point d), are of the order of 10^{-14} cm^2. The experimental data on helium mixtures will be given in a more detailed paper.

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PHONON DISPERSION MEASUREMENTS ON AN ARGON SINGLE CRYSTAL AT 4.2°K

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Phonon dispersion measurements by inelastic neutron scattering on an argon single crystal at helium temperature have been performed.

A single crystal of Ar of about 45 cm^3 volume with fcc structure has been grown from Ar with natural isotopic mixture (σ_{coh} = 0.40 barn, = 0.25 barn) and an impurity concentration ppm. The growing technique, including handling and testing of the crystal, has already been described [1]. The specimen was mounted in a cryostat such that it was completely surrounded by aluminium walls and could be cooled to liquid helium temperature.

The neutron measurements were performed with the triple axis spectrometer at the FRJ-2 reaction in Jülich. The cryostat was mounted on a special goniometer for orientation of the sample