Experimental excitation cross sections by electron impact of $np'[\frac{1}{2}]_0(n=3,4,5)$ levels of Ne

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Cross sections have been measured for excitation of $np'[\frac{1}{2}]_0(n=3,4,5)$ levels of Ne I by electron impact. The electron energy ranged from the threshold to 400 eV. For the aforesaid levels the experimental cross sections are 202, 43, and 20 ($\times 10^{-20}$ cm^2), respectively, for an electron energy of 100 eV.

I. INTRODUCTION

The study of the inelastic collisions of electrons with rare gases is an interesting theme of work, both from the experimental and the theoretical point of view. The continuously improving experimental techniques allow nowadays a more precise determination of the parameters involved in these processes and the comparison of results with the available theoretical calculations can be more relevant.

In the last decade, the measurement of excitation cross sections by electron impact has been performed for many gases (Refs. 1–4). Nevertheless few results have been reported for Ne, in spite of its interest and the abundance of levels which can be studied. Preceding works on Ne I cross sections are the experimental ones of Sharpton *et al.*[5] and Zapesochnyi *et al.*[6] and the theoretical works of Refs. 5, 7, 8, 9.

The purpose of this paper is to report the results of our measurements of cross sections for $np'[\frac{1}{2}]_0$ levels of Ne I, about which the available information is scarce, and to compare the experimental and theoretical values of the excitation cross sections. We have concentrated our work on the $np'[\frac{1}{2}]_0$ levels because they present several advantages, the most important being the small amount of indirect population through radiative cascade. Moreover, the corresponding deexcitation lines are of enough intensity to allow an accurate measurement of emission cross sections and of branching ratios. So, comparison with theoretical calculations can be significant. These measures concern the $np'[\frac{1}{2}]_0$, $n = 3,4,5$ Ne I levels whose energies[10] are 151 009 cm^{-1}, 163 745 cm^{-1}, and 168 588 cm^{-1}, respectively, above the ground state.

In this work the corresponding excitation functions of the above mentioned levels have been obtained. The correction due to radiative cascade population was made by means of a delayed coincidence technique. Finally, by using the corresponding branching ratios, the absolute values of the excitation cross sections for the levels are given as a function of the impacting electron energy.

II. EXPERIMENTAL SETUP

The experimental setup, used to measure the excitation cross sections by the optical method, consist of an electron gun which produces a beam to excite the Ne atoms in a collision chamber. A Jarrell–Ash 0.25 m monochromator was used to select the spectral lines and a UV sensitive 56 UVP photomultiplier to detect single photons. The measurements were performed from threshold to an energy of 400 eV, and the light is detected at 90° angle from the electron beam. The monochromator slit was crossed with respect to the beam direction. The experimental setup is shown in Fig. 1 and it is similar to that of previous works.[11,12] The photomultiplier output pulses were amplified and selected in amplitude. The electron beam was switched periodically at 1 KHz frequency by means of a square wave voltage applied to the control grid of the electron gun. A part of this control signal was used to gate the pulses corresponding to single photon detection in such a way that pulses corresponding to the electron beam-off case were fed to a digital counter that accumulates the background, and pulses corresponding to the beam-on case were fed to another counter that accumulates signal plus background. By using this single photon counting method accurate background corrections can be made and measurements at low pressure performed. An anode current integrator interrupts the counting when the total charge collected reaches a certain preset value. The fluctuations of the beam intensity are corrected by this method and a good accuracy can be achieved even in the case of low intensity lines.

During the measurements a continuous gas flow was maintained and the pressure was in the range 1–5 m Torr. Gas pressure was measured with Pirani and Penning gauges, previously calibrated by means of a McLeod gauge. The relative efficiency of the optical system was determined in the range 2900–5000 Å by means of deuterium and tungsten calibrated lamps.

In order to obtain the line absolute cross sections, we have compared the line emission results with those of the $5\,^1S$–$2\,^1P$ transition (4438 Å) of He, which we took as a standard. The value of the $5\,^1S$ excitation cross section obtained by the DWPO approximation[13] at 200 eV was used. The corresponding branching ratio for the $5\,^1S$–$2\,^1P$ (4438 Å) transition was taken from Ref. 14. From our measured excitation function the line emission cross section at 100 eV was determined to be 2.29×10^{-20} cm^2 in very good agreement with the recent value of Zyl *et al.*[2] (2.30×10^{-20} cm^2). We thus eliminate the effects of the errors in the absolute efficiency of the optical system detection.

We checked that the relation between the light emission in the transition and the pressure of the gas in the collision

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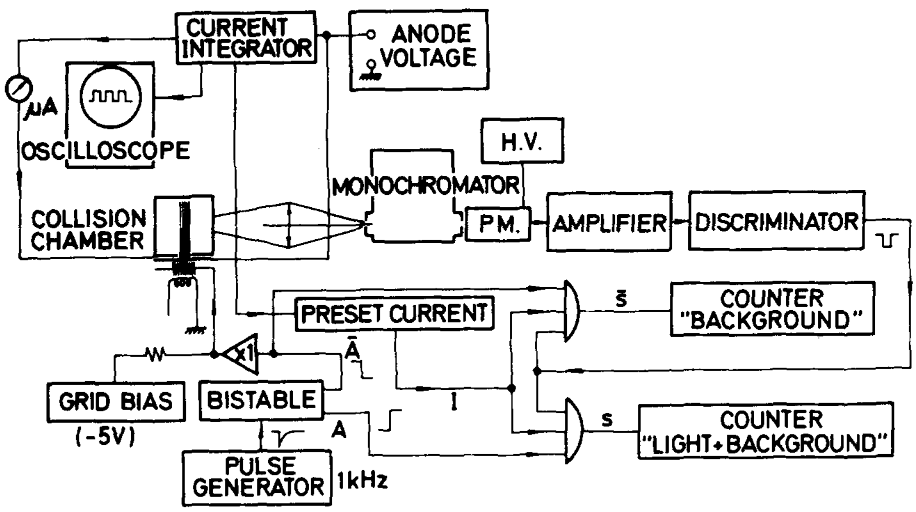

FIG. 1. Experimental setup. The bistable output $\bar{A}$ controls the grid of the electron gun. When $\bar{A}$ is "down" (-9 V) the electron beam is cutoff. In this case, $\bar{A}$ opens a gate that allows the photomultiplier pulses corresponding to background ($\bar{S}$ signals) to be stored. Simultaneously, the signal A (at $+9$ V) closes the gate that allows the storage of light plus background signals (S). After 1 ms, $\bar{A}$ is "up" ($+9$ V), the electron beam is on, and all the precedent situation is inverted. A signal (I) inhibits both gates when a preset electron charge has crossed the collision region.

chamber was linear until 20 m Torr, so that collisional secondary effects related to the lack of linearity were absent. The cascades were studied by the time analysis of the level deexcitation after pulsed excitation by using the delayed coincidence method. The influence of the cascade population were only about 5% for the studied levels.

III. RESULTS AND DISCUSSION

The $np'[\frac{1}{2}]_0 (n = 3,4,5)$ levels were studied by means of the $3s'[\frac{1}{2}]_1$–$np'[\frac{1}{2}]_0$ transitions which wavelengths are 5852, 3520, and 3058 Å, respectively. The level cross sections are obtained from the line emission cross sections through the branching ratio values. The calculated branching ratios used in this work were 0.988 for 5852 Å line, 0.442 for the 3520 Å line, and 0.378 for the 3058 Å line.

In Table I we show the results of our measurements, as compared with Sharpton *et al.*[5] values. The present experimental error is estimated as about 10% which includes the quadratic sum of the systematic and statistical errors. In this table the results for the $np'[\frac{1}{2}]_0$ levels with $n = 3,4$ are compared with those of Ref. 5, but we have not found other results for the $n = 5$ level in the literature.

In Fig. 2 we show the cross section as a function of the impinging electron energy. The experimental results have been fitted in the range 100–400 eV to a semiempirical expression of the form $\sigma(E) = \sigma_0 E^{-\alpha}$, where E represents the kinetic energy of the impinging electrons and σ_0 and α are fitting parameters. For optically forbidden transitions, as the present ones, the asymptotic behavior of the cross sections follows the law $\sigma = \sigma_0 E^{-1}$, as deduced from the Born–Bethe approximation.[15,16] The results for σ_0 and α are shown in Table II. As it can be seen the value of the exponent

TABLE I. Electron excitation cross sections of $np'[\frac{1}{2}]_0$ levels of Ne ($\times 10^{-20}$ cm^2).

levels	Present work		Reference 5 Experimental		Reference 5 Theoretical	
	100 eV	200 eV	100 eV	200 eV	100 eV	200 eV
$3p'[\frac{1}{2}]_0$	202	107	160	90	330	180
$4p'[\frac{1}{2}]_0$	43	22	64	41	80	43
$5p'[\frac{1}{2}]_0$	20	10	...	...	...	...

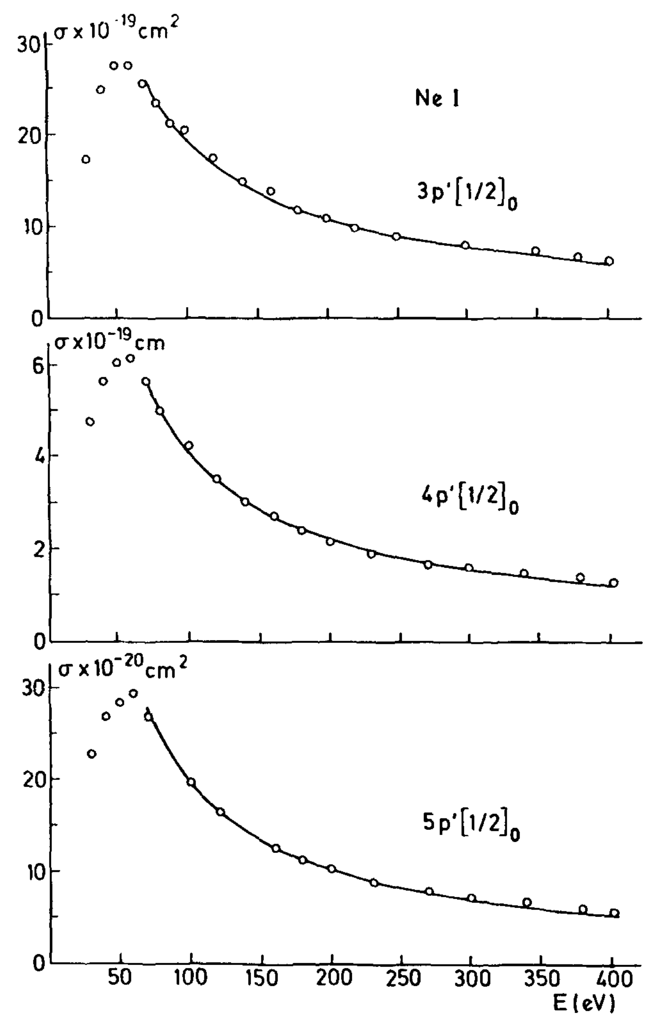

FIG. 2. Cross section for excitation of the $np'[\frac{1}{2}]_0$ ($n = 3,4,5$) levels of Ne. (O) experimental results. In full line fitting to the semiempirical expression $\sigma(E-) = \sigma_0 E^{-\alpha}$, with $\alpha = 0.87, 0.88, 0.93$, for $n = 3,4,5$, respectively.

TABLE II. Fitting of the experimental cross sections of the $np'[\frac{1}{2}]_0$ levels of Ne to the expression $\sigma(E) = \sigma_0 E^{-\alpha}$ (E in eV).

levels	$\sigma_0(\times 10^{-17}\ \mathrm{cm}^2)$	α
$3p'[\frac{1}{2}]_0$	10.5	0.87
$4p'[\frac{1}{2}]_0$	2.35	0.88
$5p'[\frac{1}{2}]_0$	1.45	0.93

α is about 0.9 for the three cases studied. This value is close to the asymptotic one.

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