Study of the spectra of electrons emitted by xenon atoms

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Autoionization states of xenon atoms play an important role in the process of UV lasing in these atoms. The process of excitation and decay of the autoionization states of the xenon atoms at energies of bombarding electrons from 20 to 50 eV was studied by the method of electron spectroscopy. The energies of electrons emitted due to decay of the autoionization states at an angle of 90° with respect to the direction of the incident electron beam were analyzed by a 127-degree electrostatic selector with a resolution of 0.07 eV. Seven lines were recorded within the energy range of emitted electron from 3 to 14 eV. New data on the position of the autoionization lines of the xenon atom have been obtained.

Introduction

The search for a spectral range of the laser radiation always presents an urgent problem. In this relation, the optical spectroscopy is complemented by new findings, for example, the electron spectroscopy of scattered electrons, which is widely presented in Refs. 1–3, as well as the electron spectroscopy of electrons emitted from metal atoms.[4–6] The experiments with atoms of inert gases have been carried out at the energy of bombarding electrons higher than 1 keV, where the Auger spectra are obtained starting from 10 eV and higher.[7,8] However, these studies did not consider the range of low energies of the exciting beam and emitted electrons. The goal of this work was to record the spectra of electrons emitted upon the electron impact with xenon atoms at the energy of the bombarding electrons lower than 50 eV and the range of the emitted electrons lower than 14 eV, which was not studied by the method of the VUV spectroscopy.

Experimental technique

The experimental setup consists of a vacuum chamber, electron spectrometer, and the electron counting and accumulation system (Fig. 1).

The vacuum chamber is made of stainless steel of the 1X18H9T type and is evacuated by two oil-vapor pumps with the total evacuation rate of 3000 liter/s. This allowed the residual pressure in the impact chamber to be decreased down to $\le 10^{-7}$ Torr with the aid of liquid nitrogen traps. The beam of xenon atoms was produced by a metal multichannel former (100 channels, diameter of 10 μm, length of 1.0 mm).

The spectrometer consists of two 127-degree electron selectors. The main elements of the spectrometer are made of polished steel and nichrome.

Two 127-degree selectors of the system of focusing lenses form a monochromator (M) and an analyzer (A), which are arranged at an angle of 90° with respect to each other. The spread of slow electrons at the monochromator exit amounts to ≈ 0.07 eV. The minimum energy of the electrons, transmitted by the analyzer A, is equal to 0.1 eV with an angular resolution of 2.9°.

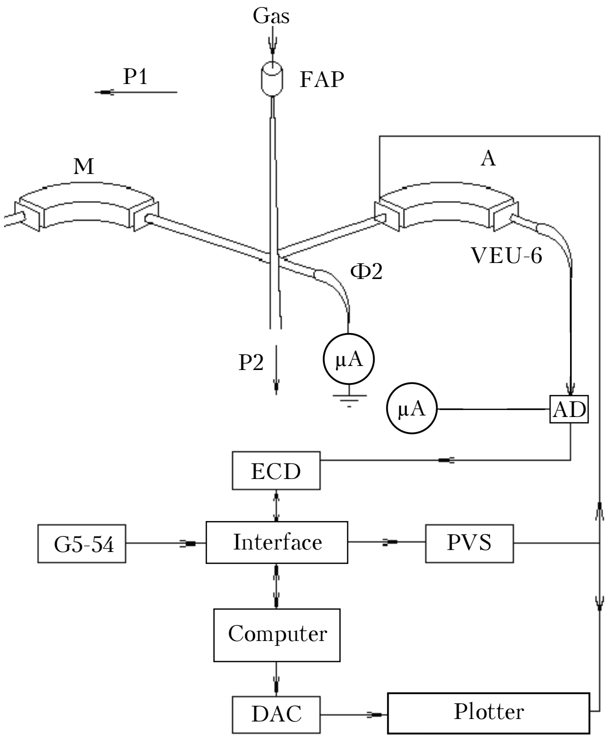

Fig. 1. Schematic diagram of the experimental setup.

The scattered electrons, analyzed by the 127-degree selector, were detected by a VEU-6 channel multiplier and amplified by a pre-amplifier (PA) before being entered into the amplitude discriminator (AD). The upper and lower discrimination levels were chosen so that they provide for the highest signal-to-noise ratio. From the discriminator, the processed pulse came to an electronic computing device (ECD). The ECD was operated by a pulse generator of the G5-54 type.

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The final result of the signal counting came to the counting module of ECD and, through an interface, to the RAM of the personal computer. The computer summarized the data from several passages and smoothed the normalized spectrum by the method of statistical processing. The final spectrum was sent to the computer memory for storage and to the monitor, as well as to a plotter through a digital-to-analog converter (DAC). The electron spectrum and the energy dependence were scanned by a programmable voltage source (PVS) with a minimum step of 0.01 eV. The programs of on-line control of the experiment with the computer and the data processing programs are written using module principle in C++ with subroutines written in Assembler.

The experiment on recording the electron spectra comprised the following stages: obtaining of the high vacuum from the gas flask to the impact chamber; thermal treatment of the electron spectrometer; activation of oxide cathodes; adjustment of M and A, filling the system with the gas under study; adjustment of the recording system and recording of the energy-loss spectrum of normal atoms (recording time of 2 h); adjustment of the computer-controlled accumulation system and recording of the energy spectra of emitted electrons.

To check the efficiency of the experimental setup, the following measurements have been carried out:

– energy-loss spectra of electrons on He atoms at the impact energy of 10–50 eV;

– energy dependences of the differential scattering cross sections of electrons on He atoms from the threshold value to the ionization boundary;

– differential elastic scattering cross section (DESCS) of electrons on He atoms with the energy scale calibrated against the resonance at the energy of 19.35 eV (Fig. 2).

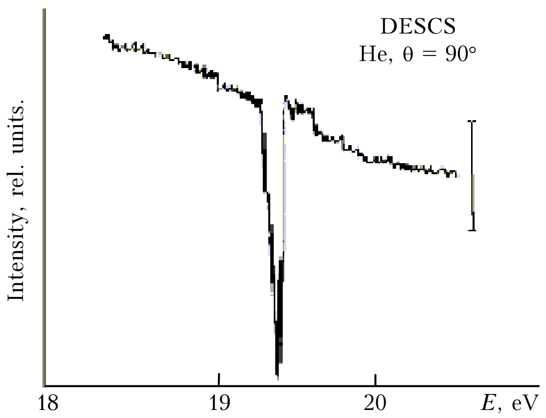

Fig. 2. Resonance $(1s2s^2)^2s$ in helium for the scattering angle at 90°.

The reliable repeatability of the measured results in He and the agreement between the data obtained and other results suggested that this experimental setup meets the main experimental requirements and provides for adequate information.

Results and discussion

The typical energy-loss spectrum of electrons on the Xe atoms is shown in Fig. 3 with the elastic peak and the group of discrete lines indicated separately.

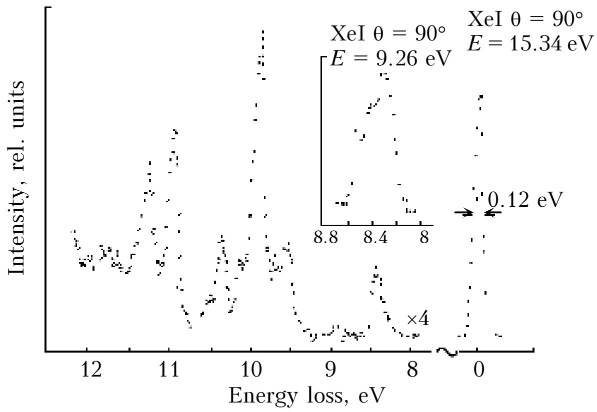

Fig. 3. Energy-loss spectrum of XeI atoms.

The positions of these lines are associated with the excitation of the xenon atom from the low-lying levels to the ionization potential. The levels with $n = 6$ are clearly resolved, while the following peaks make up groups of levels.

Figure 4 shows a part of the energy-loss spectrum from 28 to 14 eV and the spectrum of emitted electrons from 13 to 3 eV, which include intense lines.

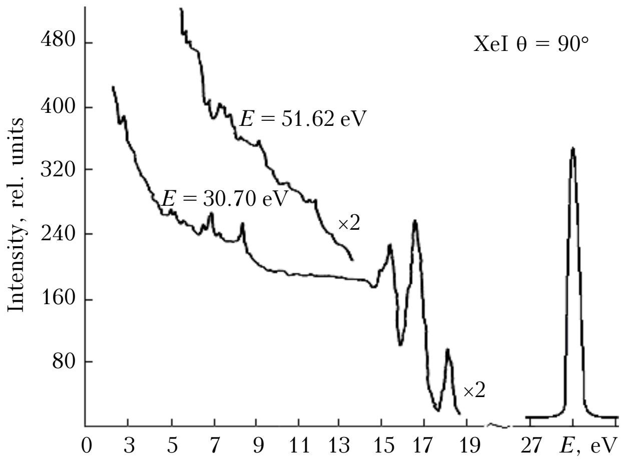

Fig. 4. Electron spectrum of Xe atoms.

The spectra were recorded at different energies of slow electrons (E = 30.70, 51.62 eV). Let us note the features revealed. As the energy of the bombarding beam decreases, the spectrum of emitted electrons is overlaps with the spectrum of inelastically scattered electrons, which is also seen in the spectra at other energies of the bombarding electron beam. Lines in the energy-loss spectrum have a significant width, which is determined by the energy resolution of the monochromator. Lines in the spectra of emitted electrons are narrow, and their width is determined by the analyzer resolution. Some lines presented can be assigned to long-lived autoionization states.

The range of the autoionization lines at the energy of 10 eV was analyzed together with the data from Refs. 7 and 8, in which the Auger spectra are presented for the case of xenon excitation by electrons at energy of several keV. The comparison of the positions of the lines presented shows that only one line, lying in a range of 10 eV, can be assigned, because in Refs. 7 and 8 the studied range starts from 8 eV. We have succeeded in the recording of the emitted electron spectra in the range below 8 eV. It should be noted that the lines presented are responsible for the decay of the autoionization states of N-subshells.

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