Luminescent spectra of noble gases and their binary mixtures under ion beam excitation

A.K. Amrenov, M.U. Khasenov

Nazarbayev University, National Laboratory Astana, Astana, Kazakhstan

Emission spectra of noble gases and their binary mixtures were measured under heavy ion beam excitation in the range of 200-1000 nm. Lines of p-s and d-p atomic transitions prevail in the gas spectra, bands of the third continuum of Ar, Kr and Xe were observed in UV region, strong bands of heteronuclear ionic molecules were observed in Ar-Xe, Ar-Kr and Kr-Xe mixtures. The presence of impurities leads to the appearance of N_2, N_2^+ bands, KrO, ArO, XeO excimer molecules' bands and atomic oxygen lines in the spectra. Radiation distribution among 2p-levels of atoms of noble gases was measured. Conclusions were made about mechanisms of level population in lasers on d-p transitions of noble gas atoms, 2p-1s-neon transitions.

Interest in the study of spectral-luminescent properties of low-temperature plasma excited by nuclear radiation stems to that fact that such plasma is an active medium of gas lasers with nuclear or beam pumping, scintillation detectors, as well as in spontaneous emission sources. Spectral-luminescent studies of noble gases excited by ionizing radiation began more than 50 years ago [1, 2]. The most detailed study was carried out by irradiation of dense gases with uranium fission fragments [3].

In this work, studies of spectral-luminescent characteristics of single component noble gases and binary mixtures excited by heavy ions are interesting from the standpoint of practical applications and were made under the same experimental conditions. The studies were conducted on the DC-60 accelerator [4]. Light was extracted through the quartz window located on the lid of the irradiation chamber. The spectrum of radiation was registered by compact QE65Pro and USB2000+ spectrometers; the relative spectral sensitivity of the installation was measured with the help of calibrated halogen lamp in the range of 400-1000 nm.

The continuous spectra of pure gases were presented by the "third continuum" of Ar, Kr and Xe, the weak band was observed in neon in the range of 200-370 nm. Strong bands of $ArXe^+$, $ArKr^+$ and $KrXe^+$ heteronuclear ionic molecules were observed in the binary mixtures of gases. The radiation of impurities is presented by N_2 and N_2^+ bands in helium and neon, N_2 bands in argon, KrO, ArO and XeO excimer molecules' bands near 557 nm, atomic oxygen lines in helium, neon, and argon. 2p-1s and 3d-2p (Paschen notations) transition lines prevail in atomic spectra.

Distribution of radiation intensity among atomic 2p-levels differs noticeably from the distribution of flow of the dissociative recombination of molecular ions among levels given at [5]. In less degree it is related to neon, the distribution of intensity is more uniform there. The significant part of the flow of Ar_2^+ dissociative recombination refers to the $2p_9$ level in argon, while about half of the radiation refers to $2p_2$ level. The half of radiation occurs from $2p_5$ level in xenon, there is only 4% of the flow of Xe_2^+ ion recombination at this level. Apparently, population of atomic 2p-levels of noble gases happens in cascade transitions from d-levels [6, 7], and the dissociative recombination of molecular ions with electrons is not the major process in population of 2p atomic levels of noble gases.

Table 1. Emission intensity distribution (in percentage) on the 2p levels of Xe in xenon and Ar-Xe, He-Xe with 1% of Xe and 0.8 kPa total pressure

P, kPa	$2p_5$	$2p_6$	$2p_7$	$2p_8$	$2p_9$	$2p_{10}$
0.27	56.0	8.0	4.3	16.8	7.4	6.4
0.53	47.2	8.6	4.4	19.8	7.6	11.3
0.81	41.6	9.1	3.6	23.0	7.9	13.7
Ar-Xe	3.8	9.4	10.5	3.5	4.8	66.9
He-Xe	1.2	42.7	1.4	11.7	9.1	33.4

References

[1] W.R. Bennett, Ann. Phys. **18** (1962) 367-420.

[2] R.J. De Young, W.R. Weaver, J. Opt. Soc. Am. **70** (1980) 500–506.

[3] V.V. Gorbunov et al., Proceedings of RFNC-VNIIEF, (2004) 148-185 (in Russian).

[4] B. Gikal et al., Physics of Particls and Nuclei Letters, **5** (2008) 642–644.

[5] V.A. Ivanov, Soviet Physics Uspekhi, **35** (1992) 17-36.

[6] M.U. Khasenov, Laser and Particle Beams, **32** (2014) 501-508.

[7] S.P. Mel'nikov et al., Lasers with Nuclear Pumping. Springer (2015).