Continuous spectra emitted by particles knocked out by an ion beam from the surface of a solid target

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(Submitted October 28, 1974)
ZhETF Pis. Red. **21**, No. 1, 77–81 (January 5, 1975)

Results are presented of an investigation of the continuous spectrum emitted by particles knocked out by an ion beam from the surface of a solid target. The hypothesis is advanced that the continuous spectrum is emitted by the knocked-out particles whose electron shells have experienced collective excitation in the knocked-out process.

In a study of the emission spectrum of excited particles produced by bombarding a solid-target surface with an ion beam we observed a continuous spectrum. On top of the spectrum emitted by the scattered beam atoms[1] and the target-material atoms.[2,3] In this communication we present the results of a more detailed study of this spectrum.

The investigations were carried out with the experimental setup described in[2]. The targets were bombarded with beams of He^+, Ne^+, and Ar^+ ions of energies 30 keV and beam-current density 200 $\mu A/cm^2$. The investigated emission was resolved into a spectrum with the aid of an ISP-51 spectrograph, whose axis was perpendicular to the plane made up by the axis of the bombarding beam and the normal to the target surface, thus ensuring that only the radiation of the excited particles moving away from the target entered into the spectrograph. The spectrum of the emission of these particles was photographed in the wavelength range 4000–7000 Å on KN-4S film. The photograph of one of these spectra is shown in Fig. 1. As seen from this figure, the emission spectrum contains a continuous spectrum in addition to the spectral lines of the excited atoms and ions of the target and beam particles. The intensity distribution in the continuous spectrum is illustrated in Fig. 2.

The results of the investigation of 22 targets (see the table) reduce to the following:

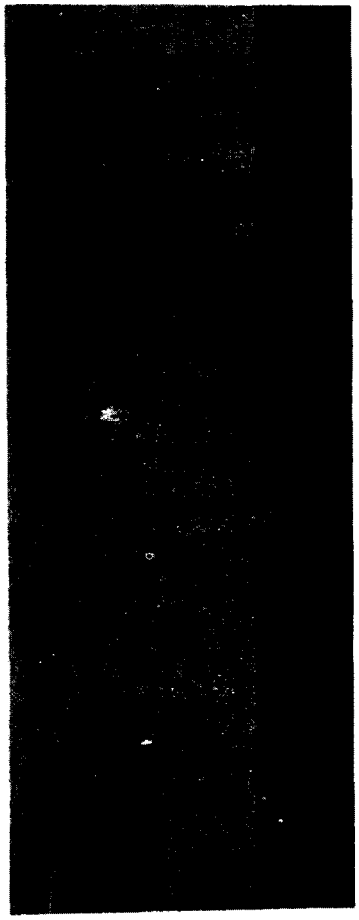

FIG. 1. Emission spectrum of Mo bombarded with Ar^+ ions.

1. The continuous spectrum was observed only in the emission of targets of nontransition metals of periods I, II, and III of the periodic system, with unfilled *nd* shell (with the exception of Pd).

Target	*)	Electron configuration	Target	*)	Electron configuration
$^{4}Be_{9}$	–	$[He]2s^2$	$^{41}Nb_{93}$	+	$[Kr]4d^45s^1$
$^{6}C_{12}$	–	$[He]2s^22p^2$	$^{42}Mo_{96}$	+	$[Kr]4d^55s^1$
$^{12}Mg_{24}$	–	$[Ne]3s^2$	$^{46}Pd_{106}$	+	$[Kr]4d^{10}$
$^{13}Al_{27}$	–	$[Ne]3s^23p^1$	$^{47}Ag_{108}$	–	$[Kr]4d^{10}5s^1$
$^{14}Si_{28}$	–	$[Ne]3s^23p^2$	$^{48}Cd_{112}$	–	$[Kr]4d^{10}5s^2$
$^{20}Ca_{40}$	–	$[Ar]4s^2$	$^{49}In_{115}$	–	$[Kr]4d^{10}5s^25p^1$
$^{23}V_{51}$	+	$[Ar]3d^34s^2$	$^{50}Sn_{119}$	–	$[Kr]4d^{10}5s^25p^2$
$^{24}Cr_{52}$	+	$[Ar]3d^5\ 4s^1$	$^{73}Ta_{181}$	+	$[Xe]4f^{14}5d^36s^2$
$^{28}Ni_{59}$	+	$[Ar]3d^84s^2$	$^{74}W_{184}$	+	$[Xe]4f^{14}5d^46s^2$
$^{29}Cu_{64}$	–	$[Ar]3d^{10}4s^1$	$^{78}Pt_{195}$	+	$[Xe]4f^{14}5d^96s^1$
$^{30}Zn_{65}$	–	$[Ar]3d^{10}4s^2$	$^{82}Pb_{207}$	–	$[Xe]4f^{14}5d^{10}6s^26p^5$

*The plus and minus signs designate the presence and absence of a continuous spectrum, respectively.

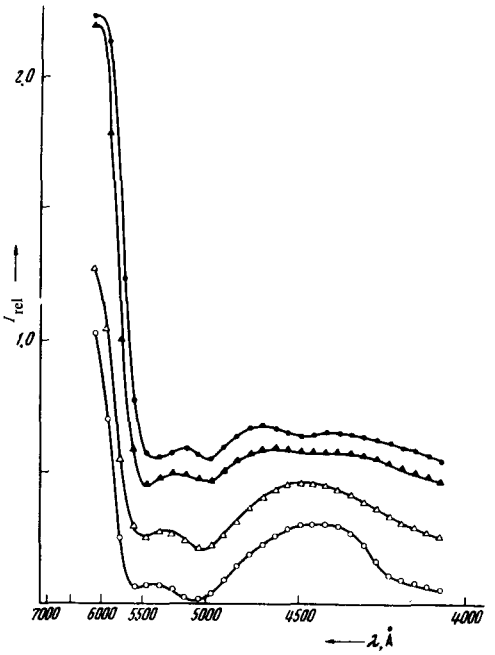

FIG. 2. Intensity distribution in continuous spectrum: ○—Mo target, Ar^+ ions; ▲-Mo target, Ne^+ ions; ○—Pt target, Ar^+ ions; △—Pt target, Ne^+ ions.

2. The intensity distribution in the continuous spectrum depends neither on the type of target nor on the type of beam particles (Fig. 2).

3. The intensity of the continuous spectrum does not change with increasing target temperature, up to 500 °C.

4. The intensity of the continuous spectrum is not changed when a positive or negative potential relative to ground (± 300 V) is applied to the target.

5. The intensity of the continuous spectrum decreases with decreasing bombarding-ion mass.

6. The continuous spectrum vanishes when oxygen or argon up to a pressure 10^{-3} mm Hg is admitted into the target chamber.

7. Prolonged roasting of the target at 1500 °C in vacuum or in an oxygen atmosphere[1)] has no effect on the intensity of the continuous spectrum.

The results allow us to draw the following preliminary conclusions:

1. The continuous spectrum cannot be emitted by the knocked-out excited particles of target material or the bombarding-beam particles, since the intensity distribution in the spectrum depends neither on the nature of the target nor on the type of beam.

2. The continuous spectrum cannot be emitted by the knocked-out excited atomic particles that emit photons with simultaneous transition of the electrons to the continuum (the radiative Auger process), for in this case the energy distribution in it would have to depend either on the type of target or on the type of the bombarding beam.

3. One cannot exclude the possibility that the observed continuous spectrum is emitted by the vibrating electron shells of the knocked-out target atoms, which experience collective excitations when they are knocked out by the bombarding-beam ions.

A hypothesis that collective excitation of the electron shell of the atom is possible was advanced by Bloch[5] back in 1933, after which it was under lively discussion,[6,7] but its existence was not proved convincingly in any experiment so far.

The investigation of the continuous spectra described in this communication is being continued for the purpose of confirming the advanced hypthesis concerning their origin.

[1)]Roasting at high temperature in an oxygen atmosphere removes the carbon impurity for the target[4]; roasting in vacuum decreases the content of alkali-metal impurities in the target.

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