K_α and K_β X-ray energy shift and broadening for Ni^{+q} ion bombardment on Cu target

Li Jing-Wen(李景文), Zhou Shu-Hua(周书华), Hu Ai-Dong(胡爱东), Zeng Xian-Tang(曾先堂) and Tian Wei(田 炜)
(China Institute of Atomic Energy, Beijing 102413)

Abstract Relative to proton bombardment, energy shift and broadening of K_α and K_β X-ray lines of Cu are observed in Ni^{+q} ion bombarding Cu atoms. This is possibly due to multiple ionization of Cu in Ni^{+q} bombardment. Increase in K X-ray transition energy and its broadening are expected when one or several of outer shielding electrons are removed from atom.

Keywords Energy shift, line broadening, Cu target, Ni ion beam

1 Introduction

The temperatures and conditions in stars and the sun show that atoms can exist in a highly ionized state. To identify the elements present and to obtain knowledge of their ionization states, the transition energies of these systems must be known. These knowledge may be obtained by means of the laboratory measurements about K X-ray energy shift and broadening.

The energies of characteristic X-rays for singly ionized atoms are well known[1], whereas the energies of X-rays for highly ionized atoms are only known for a few atoms. The study of K-shell ionization by heavy ions has been limited primarily to incident ions with low energies. Evidence presented in this paper indicates that multiple inner-shell ionization maybe takes place at much higher energies, such process produces an observable shift and broadening of the K_α and K_β X-ray energies.

In this paper we show the measurements of the energies of the K_α and K_β X-rays produced by bombarding thin Cu targets with 5 MeV proton beams and 75 MeV Ni^{+q} beams. We have observed Cu K_α, K_β line shifts in the excitation by Ni^{+q} beam as compared with those by proton beam. These energy shifts are attributed to a high probability of multiple inner-shell ionizations created by ion-atom collisions.

2 Experimental method

The experimental arrangement is described in a previous paper[2]. The experimental setup is shown in Fig.1.

In the measurements a self -supporting Cu target of about 1 mg/cm^2 was bombarded by 5 MeV proton beams and 75 MeV Ni^{+q} beam from CIAE HI-13 tandem accelerator. The target was oriented at 45° with respect to the beam. The X-rays were measured at 90° with

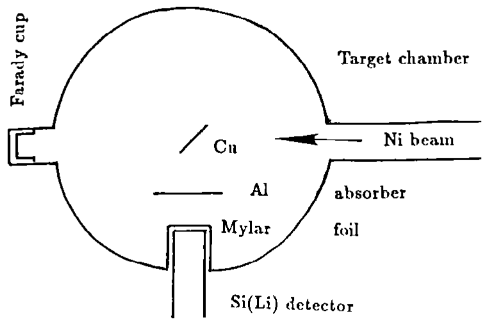

Fig.1 Experimental set-up

respect to the beam axis by a Si(Li) detector (28 mm^2×5.27 mm, at 5.9 keV FWHM = 175 eV). A Mylar window (13 μm thick) was used to isolate the Si(Li) detector from the vacuum chamber. There was an 1 cm layer-of- air between the window and the Si(Li) detector. The beam current was measured for monitoring. The spectra were recorded on a magnetic tape and then analyzed with a VAX11/780 computer. The energy calibration was done with a

Manuscript received date: 1996-03-20

^{241}Am standard X-ray source. The X-ray spectra of ^{241}Am standard X-ray source were taken before and after every experiment run to check any amplifier drift.

3 Results and discussion

In Fig.2 X-ray spectra of a thin Cu target are given. It can be seen that the energies of K_α and K_β lines are increased in the case of the Ni^{+q} beam bombarding Cu target. The full width at half -maximum (Γ) is also increased. The results of the analysis of the data for Cu are summarized in Table 1. The calibrated energies for K_α and K_β lines for the proton bombardment are consistent with the values tabulated by Bearden[1]. The K_α, K_β energy shifts are 61 eV and 170 eV for Ni^{+q} bombardment relative to the proton excitation of Cu.

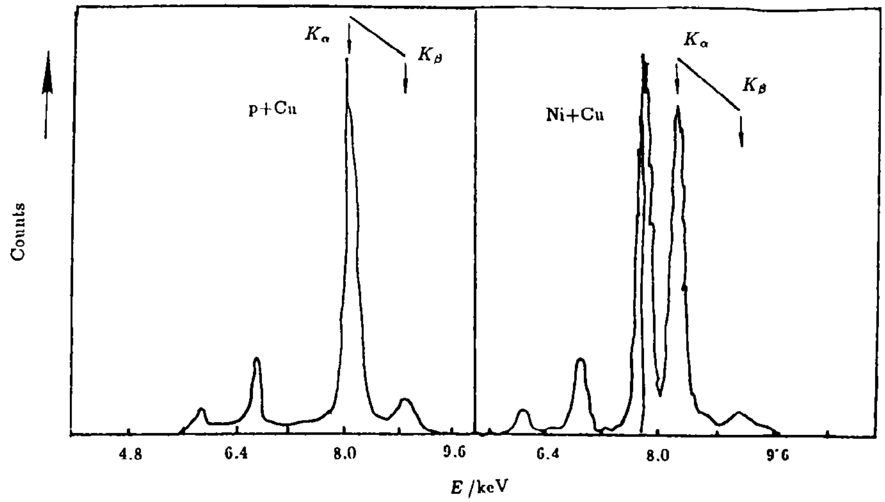

Fig.2 X-ray spectra produced by protons or nickel ions bombarding Cu target

Table 1 X-ray data for Cu in eV

	E_α	Γ_α	E_β	Γ_β	$E_\beta - E_\alpha$
p+Cu	8047	293	8971	317	924
Ni+Cu	8108	307	9141	396	1033

Richard *et al* [3] performed a similar experiments on O^{+q} (15 MeV)+Cu. Our results show the energy shift and broadening larger than their data. The difference between our results and Richard's[3] may be due to outer shell vacancies reducing shield, produced by the higher projectile energy used in our experiment.

In conclusion we have observed energy shift and broadening of K_α and K_β lines in Ni^{+q} beam bombarding Cu target. X-ray lines produced by heavy-ion bombardment appear at higher energies compared with those generated by proton excitation. The increase in X-ray energy is ascribed to multiple ionization of target atoms, which was produced by impact of heavy ions. In our case the K-shell ionization of target atoms is well understood in terms of additional L-shell vacancies produced by the heavy-ion impact, in which the so-called K X-ray satellites take place. These satellites dominate the normal K_α and K_β radiation. This effect was even observed in poor-resolution experiments with Si(Li) solid-state detectors. Therefore an increase in K X-ray transition energy can be expected when one or several of outer shielding electrons are removed from the atom by impact of heavy ions.

References

1 Bearden J A. Rev Mod Phys, 1967; 39:78

2 Dong Zhi-Qiang, Zhou Shu-Hua, Li Jing-Wen *et al.* Chin J Nucl Phys, 1991; 13:209

3 Richard P, Morgan I L, Furuta T *et al.* Phys Rev Lett, 1969; 23:1009