

Low Energy Plasmon Satellites in X-ray emission spectra of Transition elements

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ABSTRACT

We have measured X-ray fluorescence spectra of 3d transition elements with high-resolution crystal spectrometer. In order to study possible effects of chemical bonding in the fluorescence spectra, we have measured different chromium compounds. The Intensities and energies relative to the parent diagram line were determined.

Keywords: Chromium compounds, High resolution X-ray spectroscopy, Proton excitation, second order radiative contributions.

INTRODUCTION:

The diagram lines in the X-ray emission spectra correspond to electron transitions in singly ionized atoms. These diagram lines resemble atomic one-electron level structure and are usually accompanied by the second order radiative contributions known as Satellites. Satellites observed on lower energy side are called Lower Energy Satellite (LES). Intensity of these lines depends directly on the type of excitation. This can be explained by assuming that a Plasmon is excited during X-ray emission, emitting energy $\hbar\omega_p$ below the parent line. Plasmon satellites were initially observed in L X-ray emission spectra of Na, Mg and Al. Later on in the k_α emission of beryllium, graphite. Plasmon satellite exists due to sudden disturbance of electron distribution.

If Plasmon exists in Solids during X-ray emissions then High energy Satellite (HES) are observed.

EXPERIMENT:

X-ray emission spectra either with proton or photon excitation (i.e. PIXE or XRF) are generally used for measurements and are very effective for detecting low concentrations. The chemical state appears in the fine structure of the X-ray spectra. It is expected that $K_{\alpha 1,2}$ spectra are free from chemical effects as they are emitted through transition between inner shells. Chemical effects are more pronounced to be found in $K_{\beta 1,3}$ spectra as they are directly connected to 3d valence shell.

In this work we have focused on 3d transition element, Chromium (Cr). We have measured significant chemical effects on the Intensities and energies of LES.

The experiment was performed using High-Resolution crystal spectrometer. 2MeV energy was

used to accelerate protons and current of 1-2 μA was applied. Chromium compound targets, pellets were prepared. Lower beam current of the order of (28-75nA) was used, so that target is not damaged during proton bombardment.

High-Resolution crystal spectrometer consists of a target holder, a slit, a diffraction crystal and a position detector.

Emitted photons were reflected in the first order by $7.2 \times 2.6 \text{ cm}^2$ Lithium Fluoride plane crystal. Reflected photons were detected by Fuji imaging plate (IP).

The diffracted X-rays formed a 2D pattern on IP detector. The horizontal axis corresponds to energy axis of spectrum. The vertical axis increases the collection area. A slit of width 1.1mm was used to get an experimental resolution close to the natural width of the observed spectral line. The distance between IP detector and the target was 858.6nm which provided excellent angular resolution. As a result $K_{\alpha 1}$ line was achieved and second order contribution of $K_{\beta 1,3}$ diagram line was easily resolved.

Cr sample was divided into three groups Cr^0 (Cr), Cr^{3+} (Cr_2O_3) and Cr^{6+} (K_2CrO_4) according to its oxidation number. The influence of chemical structure on $K_{\beta}L^1$ and KMM lines was investigated. The results of spectra analysis are listed in Table 1 and 2.

Table 1: Intensities of second order contributions in the $K_{\beta 1,3}$ fluorescence spectra of Cr compounds.

Line	Cr	Cr_2O_3	K_2CrO_4
K_{β}'	39.10±0.91	31.00±2.5	30.90±2.6
L*			0.96±0.45
$K_{\beta 5}$	4.2±1.30	1.76±0.82	3.1±1.6
$K_{\beta}L^1$	5.20±0.35	6.05±0.54	3.03±0.92
KMM	1.62±0.15	1.45±0.52	1.36±0.68

* stands for additional lines observed in case of K_2CrO_4 between $K_{\beta 1,3}$ and $K_{\beta 5}$ lines which was observed in the case of K_2CrO_4 .

The relative intensity for K_{β}' line is given as $I(K_{\beta}')/I(K_{\beta 1,3})$ Intensities are measured and given in %age.

Table 2: Energies (in eV) of second order contributions in the $K_{\beta_{1,3}}$ fluorescence spectra of Cr compounds relative to the $K_{\beta_{1,3}}$ diagram line.

Line	Cr	Cr ₂ O ₃	K ₂ CrO ₄
K_{β}'	-9.64±0.18	-11.6±0.34	-10.23±0.75
L			28.90±1.3
$K_{\beta 5}$	42.2±1.2	36.4±1.2	43.1±1.8
$K_{\beta L}^1$	52.85±0.32	52.25±0.40	55.92±0.64

According to the results for the K_{β}' line we can write down the following relations.

$$I(\text{Cr}^0) > I(\text{Cr}^{3+}) \quad (1)$$

$$I(\text{Cr}^{3+}) \geq I(\text{Cr}^{6+}) \quad (2)$$

$$\delta E(\text{Cr}^{3+}) > \delta E(\text{Cr}^{6+}) \quad (3)$$

$$\delta E(\text{Cr}^{6+}) \geq \delta E(\text{Cr}^0) \quad (4)$$

Where I represents Intensity and δE represents energy position, relatively to the $K_{\beta_{1,3}}$ line.

Similarly we can write down relations for $K_{\beta 5}$ line.

$$I(\text{Cr}^0) \geq I(\text{Cr}^{6+}) \quad (5)$$

$$I(\text{Cr}^{6+}) \geq I(\text{Cr}^{3+}) \quad (6)$$

$$\delta E(\text{Cr}^0) > \delta E(\text{Cr}^{6+}) \quad (7)$$

$$\delta E(\text{Cr}^{6+}) \geq \delta E(\text{Cr}^{3+}) \quad (8)$$

Where I represents intensity relative to sum of $K_{\beta_{1,3}}$ and K_{β}' lines.

δE represents energy position relative to the $K_{\beta_{1,3}}$ line.

CONCLUSION:

Proton induced $K_{\beta_{1,3}}$ x-ray fluorescence spectra of Cr have been measured with high resolution crystal spectrometer.

Second order contributions (K_{β}' , $K_{\beta 5}$, $K_{\beta L}^1$, KMM) were clearly resolved. We determined their energies and intensities. This effect was found most clearly pronounced in energy position of K_{β}' line

relative to $K_{\beta_{1,3}}$ line. The same effect has been found for energy of $K_{\beta L}^1$ satellite line relative to $K_{\beta_{1,3}}$ line.

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