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Low Energy Plasmon Satellites in X-ray Emission Spectra of Transition Element

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Abstract-
We have Show the involvement of Low Energy Plasmon Satellites in X-ray Emission Spectra of Transition Element (Sc , NiO , Cu , CuO)

Keywords

Surface Plasmon Satellites , Relative Intensity & Energy Separation

Introduction-

In the characteristic X-ray Spectra, Diagram as well as non Diagram lines are present. Those lines which fit in the conventional energy level diagram are called Diagram lines. & those lines which do not fit in the conventional energy level diagram are called non diagram lines. It is also known as "Satellites or Second order lines". Satellites are generally of weak intensity lines & are found close to more intense parent line. The satellites which are observed on higher energy side are called high energy satellites (HES) whereas those are observed on lower energy side are called lower energy satellites (LES). First Siegbahn & Stenstroem observed these satellites in the K-Spectra of element from Cr (24) to Ge (32) while coster theraeus & Richtmyer in the L-Spectra of element from Cu (29) to Sb (51) & Hajlmar, Hindberg & Hirsch in the M-Spectra of elements from Yb (70) to U (92). Several theories were proposed from time to time to explain the origin of these satellites. Out of these theories the plasmon theory is found to be the most suitable theory especially for those satellites.

Plasmon theory was first proposed by Bohm & pines which are extended by Housten, Ferrel, Noziers & Pines. According to this theory the low energy plasmon satellites are emitted when valence electron excites a plasmon during the annihilation of core hole conversely if Plasmon pre exists, its energy add up to the energy of diagram line.

The involvement of Plasmon oscillation in the X-ray emission or absorption spectra of solids has been widely studied during the last few decades and has been recognized that the electron –electron interaction has played an important role.

This Paper is devoted to Show the involvement of Low Energy Plasmon Satellites in X-ray Emission Spectra of Transition Element (Sc , NiO , Cu , CuO)

According to Plasmon theory , if the valence electron , before filling the core vacancy , also excites a Plasmon ,then the energy $\hbar\omega_p$ needed for the excitation of Plasmon oscillation is taken from the transiting valence electron so that the emitted radiation will be derived off an energy $\hbar\omega_p$ and a low energy satellites will emitted whose sepration from the main X-ray line will correspond to $\hbar\omega_p$. On the other hand if the Plasmon pre exists , during the X-ray emission process , then , on its decay it can give its energy to the transiting valence electron before it annihilates the core vacancy . Thus the energy of emitted X-ray photon will be higher than the main emission line and by an amount $\hbar\omega_p$ giving rise to high energy satellite .

MATHEMATICAL CALCULATION –

In order to confirm the involvement of Plasmon in the emission of X-ray satellites the relative intensity of single Plasmon satellites must be calculated . In this process first we deal with mathematical details of canonical transformation carried out over the model Hamiltonian of the system . Thus the energy separation ΔE of the low and high energy Plasmon satellite from the corresponding main line should be equal to the quantum of Plasmon energy $\hbar\omega_p$ which is given by [10}

$$\Delta E = \hbar\omega p = 28.8 \sqrt{\left(\frac{Z.\sigma}{w}\right)} \qquad 1$$

Where Z = No.of unpaired electrons ,

σ = Specific gravity

ω = Molecular Weight

This equation can be derived as given below .

From the classical consideration ,we get the frequency of Plasmon oscillation as

$$\omega p = \left(\frac{4\pi ne^2}{m}\right)^{1/2} \qquad 2$$

Hence the amount of energy given to Plasmon becomes

$$E_p = \hbar\omega_p = \hbar \left(\frac{4\pi ne^2}{m}\right)^{1/2}$$

In this equation we can write $n = \frac{L\sigma Z}{w}$

Where σ , Z and W are defined above and L is the Avogadro number .By putting the numerical value of constant , we get the Plasmon energy as

$$\Delta E = \hbar\omega p = 28.8 \sqrt{\left(\frac{Z.\sigma}{w}\right)} \qquad 3$$

And The Surface Plasmon Energy

$$Es = Ep / \sqrt{2} \qquad 4$$

Our calculated values of ΔE have been compared with the Scrocco's experimental value. And We have also calculated the relative intensity of plasmon satellites, which is different in different processes. If the excitation of plasmon occurs during the transport of the electron through the solid, it is known as extrinsic process of plasmon excitation. The plasmon can also be excited by another method known as intrinsic process. In this process, excitation of plasmon takes place simultaneously with creation of a hole. Bradshaw et al have further divided core hole excitation into two classes,

1 - Where the number of slow electrons are conserved.

2 - Where the number of slow electrons are not conserved

When the number of slow electron is not conserved, plasmon satellite will be strong . For this process, we have used a formula for relative intensity of both the low and high energy X-ray satellites which is given as

$$i_1 = 0.12\, r_s - 0.1 \qquad 5$$

Second formula for relative intensity is the intrinsic process, when the number of slow electrons in conserved. In this case Plasmon satellites will be weak. Srivastava et al. (1974) has derived the formula for the relative intensity of high energy single Plasmon satellite by making several canonical transformation in the Hamiltonian given by Browers (1967). The formula is

$$i_2 = \alpha\, [\, 1 - 3/2\, \sqrt{(2/\beta)}\, \tan^{-1} \sqrt{\beta/2} \;+\; 1/(2+\beta)\,] \qquad 6$$

Where $\alpha = e^2\, kc / \pi\hbar\omega_p = 0.166\, r_s$ and $\beta = kc / k_f = 0.814\, r_s^{1/2}$

Further, Srivastava et al. have also derived an expression for the relative intensity of high energy double Plasmon satellites by extending the Brower's Hamiltonian. The expression obtained by them is given below.

$$i_3 = \alpha^2 / 4\sqrt{\beta}\, (\tan^{-1}\sqrt{\beta}) \qquad 7$$

Where α and β has the same significance as in equation (2).

Using the equation (5,6,7), the author has for the first time, calculated the relative intensity Low Energy

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Table Energy sepration ΔE & Relative Intensity Transition Element

S.No.	Element	Z	ΔE Calculated by Srivasta et al.(14)		ΔE observed		Calculated relative intensity, using observed values of Salem et al.		Observed relative intensity	
			$\hbar\omega p$	$\hbar\omega s$	Salem et al.(16)	Deutsch et al.(15)	I_p	I_s	Salem et al.(16)	Deutsch et al.(15)
1	Sc	1	6.79	4.80	5.73	-	0.074	-	0.069	-

2	**NiO**	**3**	**15.75**	**11.14**	**11.29**	**-**	**-**	**0.042**	**0.062**	**-**
3	**Cu**	**1**	**10.79**	**7.63**	**12.34**	**8.4**	**-**	**0.069**	**0.062**	**0.105**
4	**CuO**	**3**	**14.15**	**10.007**	**12.81**	**-**	**-**	**0.034**	**0.063**	**-**