X-Ray Satellites in the Lα1 Region of 4d Transition Element

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Abstract- We have used Plasmon theory [13,14] to explain Energy Satellites and relative intensity of high energy X-ray satellites Lα3 , Lα4 & Lα5 with respect to Lα1 parent line in 4d Transition Metal (Zr , Nb , Mo , Ru , Rh , Pd , Ag and Cd) and estimated values are in agreement with the calculated values of Surendra Poornia and S.N.Soni[15].

Index Terms- Surface Plasmon Satellites , Relative Intensity & Energy Sepration

I. 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 to Ge while coster theraeus & Richtmyer in the L-Spectra of element from Cu to Sb & Hajlmar, Hindberg & Hirsch in the M-Spectra of elements from Yb to U. 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 radiation less reorganization of electronic shell of an atom is known as Auger effect. Auger satellites have also been observed by Korbar and Mehlhorn [1] Haynes et at. [2] Edward and Rudd [3]. Theoretical explanation for K series Auger spectrum was given by Burhop and Asaad [4] using intermediate coupling. Later on more refined theory, using relativistic and configuration interaction has been used by Listengarter [5] and Asaad [6]

In Auger primary spectra, one can also observe secondary electron peaks close to the primary peaks are produced by incident electrons which have undergone well energy losses. The most common source of such energy loss in the excitation of collective plasma oscillations of the electrons in the solid. This gives rise to a series of plasma peaks of decreasing magnitude spaced by energy $\hbar\omega_p$ where ω_p is the frequency of plasma oscillation.

Auger peaks are also broadened by small energy losses suffered by the escaping electrons. This gives rise to a satellite on the low energy of the Auger peak. Energy loss peaks have well defined energy with to primary energy.

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 Plasmon theory [13,14] to explain the Energy Satellites and relative intensity of high energy X-ray satellites **Lα3 , Lα4 & Lα5 with respect to Lα1 parent line in 4d Transition Metal (Zr , Nb , Mo , Ru , Rh , Pd , Ag and Cd)** and estimated values are in agreement with the calculated values of Surendra Poornia and S.N.Soni[15].

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.

Surendra Poornia and S.N.Soni have observed low and high energy satellite peaks in 4d Transition Metal (Zr , Nb , Mo , Ru , Rh , Pd , Ag and Cd) A close approximation of their tables shows that some satellites are at a distance of $\hbar\omega_p$ (Plasmon energy) from the main emission line . This observation forced us to think that these might be due to Plasmons emission and absorption.

II. 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 [13]

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

Where $\quad$ Z = No.of unpaired electrons taking part in plasma oscillation

$\quad\quad$ σ = Specific gravity
$\quad\quad$ ω = Molecular Weight

This equation can be derived as given below.

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

$$\omega p = \left(\frac{4\pi n e^2}{m}\right)^{1/2} \quad\quad \mathbf{2}$$

Hence the amount of energy given to Plasmon becomes

$$E_p = \hbar\omega p = \hbar \left(\frac{4\pi n e^2}{m}\right)^{1/2}$$

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

, 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

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

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

The Author has calculated relative intensity in both the cases with new modification in the light of Bradshaw [12] and Lengreth [13] work, which explains that not only intrinsic process but extrinsic process and their relative contribution may also contribute in relative intensities. The combined effect of intrinsic and extrinsic plasmon excitation intensity variation was suggested by Lengreth as:

$$I= \ Is \ / \ Im = \alpha^n \ \sum_{m=0}^{n} \frac{\left(\frac{\beta}{\alpha}\right)^m}{m!} \quad\quad \mathbf{4}$$

The value of β is taken as $\beta = 0.12 r_s$ which is purely intrinsic, $r_s = (47.11/ \hbar w_s)^{2/3}$ is dimensionless parameter and $\alpha = 0.47 \ r_s^{1/2}$ in the place of $\alpha = (1+l/L)^{-1}$ used by Pardee et. al.(14) . The equation (3) contains a series of terms. The first term of the equation is purely extrinsic, while second term is purely intrinsic. The other terms are containing the relative contributions of both extrinsic and intrinsic. The specialty of this formula is that each term alone or simultaneously with other terms is able to give the relative intensity. This formula also includes both the categories mentioned by Bradshaw and gives better results as compared than traditional methods for calculation of the relative intensity. Using the values of α, β and r_s in equation (4)

Using the equation (4), the author has for the first time, calculated the relative intensity of high energy X-ray satellites **Lα_3 , Lα_4 & Lα_5 with respect to Lα_1 parent line in 4d Transition Metal (Zr , Nb , Mo , Ru , Rh , Pd , Ag and Cd)** metals. Our calculated and estimated values are in agreement with the calculated values of Surendra Poonia and S.N.Soni(11).

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Energy sepration ΔE at Lα1 satellite of 4-d Transistion element

S.No.	SYMBOL	Z	W	Sp.Gravity	Exper. Value [Ref. 15]	Author Value	Satell. Name
1	Zr(40)	1	91.224	6.51	6.54	5.44	Lα3
2					10.64	10.88	Lα5
3	Nb(41)	1	92.906	8.58	6.51	6.19	Lα3
4					10.61	12.38	Lα5
5	Mo(42)	1	95.94	10.28	6.54	6.67	Lα4
6					8.84	9.43	Lα5
7	Ru(44)	1	101.07	12.45	6.85	7.15	Lα3
8					9.55	10.11	Lα4
9					11.95	14.30	Lα5
10	Rh(45)	1	102.91	12.41	7.36	7.07	Lα3
11					9.96	10.00	Lα4
12					12.66	14.14	Lα5
13	Pd(46)	1	106.42	12.02	7.59	6.84	Lα3
14					10.39	9.68	Lα4
15					13.49	13.68	Lα5
16	Ag(47)	2	107.87	10.5	8.09	8.99	Lα3
17					10.69	12.71	Lα4
18					13.99	17.98	Lα5
19	Cd(48)	2	112.41	8.64	8.77	7.98	Lα3
20					11.47	11.29	Lα4
21					14.77	15.96	Lα5

Relative Intensity of Lα1 satellite of 4-d Transition element

S.No.	SYMBOL	Surface Energy	Bulk Energy	Rs	Alpha	beta	Author intensity	Exp. Intensity [Ref.15]	Satell. Name
1	Zr(40)	5.44	7.69	4.22	0.97	0.5060	0.76180	0.7840591	Lα3
2							0.50600	0.4177052	Lα5
3	Nb(41)	6.19	8.75	3.87	0.92	0.4644	0.70000	0.7780185	Lα3
4							0.46440	0.4153178	Lα5
5	Mo(42)	6.67	9.43	3.68	0.90	0.4419	0.66780	0.7214661	Lα4
7							0.44190	0.4019253	Lα5
9	Ru(44)	7.15	10.11	3.52	0.88	0.4218	0.84370	0.7837573	Lα3
10							0.63890	0.6746709	Lα4
11							0.42180	0.3891727	Lα5
13	Rh(45)	7.07	10.00	3.54	0.88	0.4248	0.84970	0.8655837	Lα3
14							0.64320	0.7143737	Lα4
15							0.42480	0.3976648	Lα5
17	Pd(46)	6.84	9.68	3.62	0.89	0.4342	0.86844	0.8624479	Lα3
18							0.65670	0.6916922	Lα4
19							0.43420	0.4220774	Lα5
21	Ag(47)	8.99	12.71	3.02	0.82	0.3622	0.88480	0.8580864	Lα3
22							0.72432	0.6724729	Lα4
23							0.44240	0.4252396	Lα5
25	Cd(48)	7.98	11.29	3.27	0.85	0.3918	0.78365	0.8258238	Lα3
26							0.59610	0.6572864	Lα4
27							0.39180	0.4305464	Lα5