Satellites of the K_{β_1} Line of Elements from *Fe* to *Zn*

By

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In the course of experiments to determine the relative position of the absorption edge and the $K\beta_2$ line for the elements from *Fe* to *Zn* the author has found several new satellites on the short side of $K\beta_1$ and $K\beta_2$, which seem to be the continuation of β'' and β''' observed by Druyvesteyn[1] below *Fe*.

Experimental Method

The spectrograms were taken with a spectrograph of Seeman's "Loch Kamera" type made in this laboratory. For the X-ray source, a Hilger "Shearer" tube was used and was evacuated by a Cenco oil pump. The tube was excited by a transformer at 4–5 K.V., and the current through it was about 10 milliamperes. 3 to 10 hours of exposure were given to one plate. Hilger anticathodes were used in the case of *Fe* and *Cu*, but in other cases *Co*, *Ni* and *Zn* were deposited electrically on the *Cu* anticathode and were used.

For the measurement of wave-lengths, the $K\beta_1$ and $K\beta_2$ lines were taken as reference from Siegbahn's "The spectroscopy of X-rays." The lines in question were very weak, and somewhat diffuse, and so the estimation was very difficult. The error may have been from ± 0.3 to ± 0.5 x.u.

The Results

The lines observed are (1) between β_1 and β_2, and (2) on the short side of β_2 and seem, as mentioned above, to be the continuation

1. M. J. Druyvesteyn: Zs. f. Phys., **43**. 707 (1927).

of Druyvesteyn's β'' and β''', but for the present, they are denoted (β'') and (β''') respectively. Their wave-lengths and $\frac{\nu}{R}$ values are tabulated in Tables I and II.

Table I

Wave-Lengths of Satellites of K_{β_1}

		β_1	(β'')	β_2	(β''')	Dispersion ($X.U./mm$)
26	Fe	1752.72	1744.70	1740.6	1737.57	16.1
27	Co	1617.13	1610.14	1605.4	1602.68	16.6
28	Ni	1497.03	1490.08	1485.4	1483.14	16.2
29	Cu	1389.33	1382.17	1378.0		16.1
30	Zn	1292.71	1284.75	1281.1		14.7

Table II

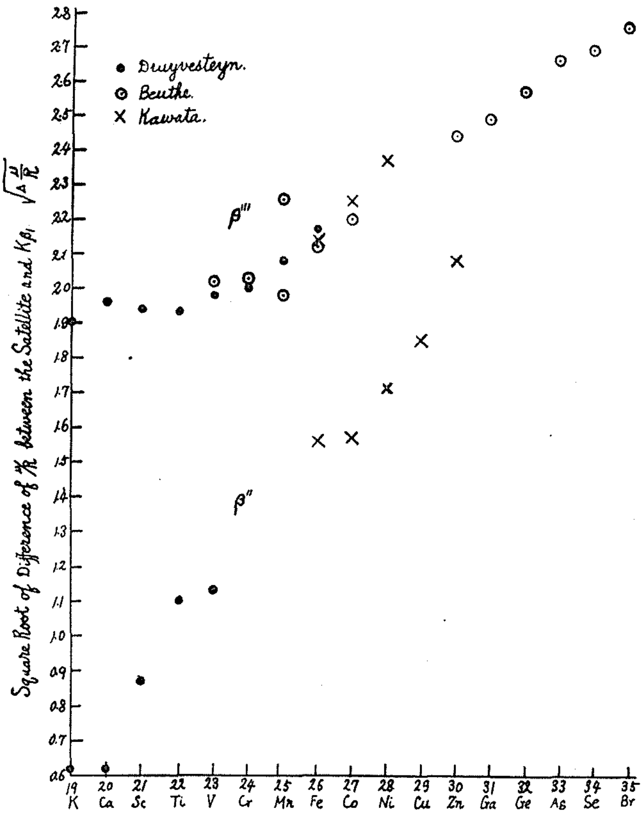
$\frac{\nu}{R}$ Values of Satellites

		β_1	(β'')	β_2	(β''')
26	Fe	519.90	522.32	523.54	524.45
27	Co	563.51	565.97	567.63	568.58
28	Ni	608.72	611.56	613.48	614.41
29	Cu	655.91	659.32	661.30	
30	Zn	704.93	709.27	711.31	

Table III

Difference between $\frac{\nu}{R}$ of β''', (β'''), β'' and (β'') and that of β_1

		β''	(β'')	β'''	(β'')
19	K	0.39		3.59	
20	Ca	0.38		3.83	
21	Sc	0.76		3.77	
22	Ti	1.20		3.72	
23	V	1.26		3.92	
24	Cr			4.00	
25	Mn			4.34	
26	Fe		2.42	4.69	4.55
27	Co		2.46		5.07
28	Ni		2.91		5.62
29	Cu		3.41		
30	Zn		4.34		



Both the (β'') and (β''') lines were well marked for the elements *Fe, Co* and *Ni*. But with respect to *Cu*, the (β''') line was very weak and scarcely separated from β_2 and its position could not be estimated; in the case of *Zn* it has not yet been obtained.

Discussion

From the above results, it is seen that (β''') of *Fe* is practically coincident with β''' observed by Druyvesteyn, and (β''') of *Co* and *Ni* seems to be its continuation, and (β'') from *Fe* to *Zn* also seems to be the continuation of β'' below V. (Compare Table III.)

Now, according to Druyvesteyn, β''' is a spark line of the type of $(KL-LM)$ and is shown to be calculated by the formula[1]

$$(KL-LM)_Z-(K-M)_Z=(L_{Z+1}-L_Z)-(M_{Z+1}-M_Z).$$

1. For the value of L Druyvesteyn has taken that of L_{III}.

Comparing the $\Delta\frac{\nu}{R}$ values of β''' and (β''') in Table III with the values calculated by this scheme, the agreement between these is found to be satisfactory.

Next, with regard to β'', Druyvesteyn is inclined to explain it as due to the transition of $(KM-MM)$. But here much difficulty is encountered. If the ordinary selection rule is assumed to hold good in this case, the energy difference between β'' and β_1 may be approximately

$$\{(K_Z+M_{?Z+1})-(M_{?Z}+M_{II\ III,\ Z'})\}-(K_Z-M_{II\ III,\ Z})$$
$$=M_{?Z+1}-M_{?Z})-(M_{II\ III,\ Z'}-M_{II\ III,\ Z}),$$

where $M_?$ denotes some one of M_Z's, and $M_{II\ III,\ Z'}$ is an energy of $M_{II\ III,\ Z}$ effected by $M_?$. Then as this value can not be greater than $(M_{I,\ Z+1}-M_{I,\ Z})$, which is at most 1 with $\frac{\nu}{R}$ as the unit at Zn, and is generally a fraction of 1, the observed $\Delta\frac{\nu}{R}$ seems too large. Even by disregarding the selection rule and assigning all possible transitions, no adequate form can be found to explain the experimental $\Delta\frac{\nu}{R}$ value. Some of the modes of transition give too large and others give too small values.

Now, Beuthe[1] has reported an interesting result in a recent paper. He has found a satellite β_y on the short side of $K\beta_2$ for the elements V, Cr, Mn, Fe and Co, and on the long side of $K\beta_2$ for higher elements than Zn.

According to the explanation given by Beuthe for the origin of β_y, one swiftly moving electron strikes an atom and ejects one electron from the K- and the L-ring simultaneously, then one M-electron falls into the ionized L-ring and from there into the ionized K-ring, the added energy thus appearing as

$$L_1=LK\alpha_1+L L\alpha_1=K-M'_V,$$
$$L_2=LK\alpha_1+L L\alpha_2=K-M'_{IV},$$
$$L_3=LK\alpha_2+L L\beta_1=K-M'_{IV}.$$

The calculated values of β_y (as $K\alpha_1+L\alpha_1$) agree fairly well with his observed values.

Now his observed position of $Fe\ \beta_y\left(524.41 \text{ in } \frac{\nu}{R} \text{ units}\right)$ just coincides with the author's $Fe\ (\beta''')$, and $Co\beta_y$ practically with $Co\ (\beta''')$.

1. H. Beuthe: Zs. f. Phys., **60**, 603, 1930.

Beuthe's β_y line also coincides with Druyvesteyn's β''' for the elements *V*, *Cr* and *Mn*. Thus it is indubitable that β''', (β''') and β_y indicate the same thing, at least within this region. But two different theories are proposed by Druyvesteyn and Beuthe, of which Druyvesteyn's scheme seems to give closer agreement with the observed values, but no decision as to which of these two theories is the better need be given here.

The author then applied Beuthe's scheme for the explanation of the origin of β'' (or (β'')). As the transition $K-M'_{IV\,V}$ is assumed for β_y which is undoubtedly identical with β''' or (β'''), for the occurrence of β'' the transition $K-M'_{II\,III}$ should be assigned. But there follow the two difficult points :—

(1) The selection rule must be broken whether for the transition from the $M'_{II\,III}$ level to the L level or for that from the L level to the K level.

(2) If we take $M'_{II\,III}$ as very nearly equal to $M_{II\,III}$, we get only the line β_1. In reality we should take into account the screening effect of the inner level. So if we consider this effect not only in the present case but also in the preceding case (the transition $K-M'_{IV\,V}$) the energy difference between β''' and β'' must be nearly equal to the difference between $M'_{II\,III}$ and $M'_{IV\,V}$, which would lie between $M_{II\,III,\,Z}-M_{IV\,V,\,Z}$ and $M_{II\,III,\,Z+1}-M_{IV\,V,\,Z+1}$.

The observed value of the difference seems too small, especially for the higher elements.

In connection with these two theories another theory is put forward by Richtmyer,[1] as namely that there are two-electron jumps into the vacancies in a doubly ionized atom. This theory, of course, fits the (β''') line fairly well, but still seems incapable of explaining the (β'') line.

In conclusion the author wishes to express his cordial thanks to Prof. Ishino for his kind guidance in the present research.

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1. F. K. Richtmyer: Jour. Frank. Inst., **208**, 325, 1929.