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K-Shell Fluorescence Yield for Beryllium, Boron, and Carbon

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K-Shell Fluorescence Yield for Beryllium, Boron, and Carbon*

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The K-shell fluorescence yield ω_K for Be, B, and C was determined from intensity measurements of the K emission bands excited in fluorescence with the synchrotron radiation of the 7.5 GeV electron synchrotron DESY. The following values were obtained:

Beryllium	$\omega_K = 3.6 \times 10^{-4}$
Boron	$\omega_K = 5.7 \times 10^{-4}$
Carbon (Graphite)	$\omega_K = 8.8 \times 10^{-4}$

the mean error being ±30 %. The results and those of previous measurements are discussed.

Several papers[1-4] dealing with the fluorescence yield of elements with atomic number $Z < 10$ have been published recently. The values obtained by different authors are not in good agreement, therefore further measurements seemed to be necessary.

A new method was used to determine the K-shell fluorescence yield ω_K of Be, B, and C. Synchrotron radiation of the 7.5 GeV electron synchrotron DESY falls onto a flourescer under an angle of incidence of about 70°, and the fluorescence radiation being taken off under an angle of 90° with respect to the primary beam enters a 2 m concave grating spectrometer. For the evaluation of ω_K the photon flux of the fluorescer is determined as follows. Let $N_K\omega_K$ be the number of K photons emitted per second and steradian by the fluorescer in the direction of the spectrometer entrance slit. Then N_K can be calculated by integrating the absolute intensity of the synchrotron radiation over the wavelength and taking into account the absorption coefficients of the target materials for the primary photons and the fluorescence radiation after a formula which is similar to that given by Dick and Lucas[2]. The absolute intensity of the synchrotron radiation the wavelength distribution of which is well known[5,6] was determined with an error of ±10 % from beam current measurements[7,8]. Considering the uncertainty of the absorption coefficients[9-11] the mean error of N_K amounts to ±22 %. The fluorescence yield ω_K is calculated from the data of intensity measurements of the K emission bands[12] using the formula[13]

$$I_{max} = N_K \omega_K L, \qquad (1)$$

where I_{max} is the counting rate measured in the maximum of the K emission band in question and L is a quantity which is determined by the characteristics of the spectrometer and may be written

$$L = g_S R_G f_E Y_D, \qquad (2)$$

where g_S is the geometry factor, i. e., the fraction of the emitted intensity of the fluorescer which is accepted by the spectrometer, R_G the reflecting power of the grating, f_E a factor giving the proportion of the peak intensity to the total intensity of the emission band and Y_D the quantum yield of the detector[14].

The value of L was obtained by calculating g_S and measuring R_G, f_E and Y_D and this value was checked by intensity measurements of the K radiations of C and Be excited by electron impact. The absolute intensities N_{eff} (emitted K photons per electron and steradian) of the X-ray sources were calculated using the K X-ray quantum yield coefficients determined by Campbell[4]. A comparison of the measured peak intensities I'_{max} of the spectra excited by electron impact with the values calculated from the quantity L and the absolute intensities N_{eff} after the equation

$$I'_{max} = N_{eff} L \qquad (3)$$

gave an agreement within a few percent, thus confirming the reliability of the determined value of L.

The values obtained for the fluorescence yield are listed in Tab. 1 together with all values determined so far experimentally for Be, B, and C and theoretical calculations of McGuire[1] for B and C. Our value for B is in agreement with McGuire's calculation while for our value of C this is not the case.

The experimental values of Dick and Lucas[2] for Be, B and C and of Crone[15] for C are within the error bars of our results, while Hink and Paschke's[3] value for C is closer to McGuire's calculation.

In Fig. 1 the K-shell fluorescence yield for elements of Z = 4...47 is shown in a plot after Byrne and Howarth[16]. The straight line representing the equa-

tion

$$\ln(1/\omega_K - 1) = -3.94 \ln Z + 13.5 \qquad (4)$$

has been taken from a calculation of Kostroun et al.[17] and fits best the theoretical data of these authors for $15 < Z < 70$. The values of Crone[15] for C, N, and O were determined relative to neon for which a theoretical value ($\omega_K = 8.1 \times 10^{-3}$) was used. A better value for neon seems to be that lying on the straight line ($\omega_K = 1.2 \times 10^{-2}$) in Fig. 1. Relative to this value Crone's results are for carbon $\omega_K = 1.3 \times 10^{-3}$, nitrogen $\omega_K = 2.2 \times 10^{-3}$, and oxygen $\omega_K = 3.2 \times 10^{-3}$ which fit the straight line more closely than the original values. The values for $Z = 13...47$ of more recent and reliable measurments[18-23] fit this line best. Our results and those of Dick and Lucas[2] are close enough to the straight line so that one may say that Eq. (4) is a good approximation for the dependence for the K-shell fluorescence yield upon the atomic number at least down to $Z = 4$.

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Table 1 Fluorescence yield for Be, B, and C in units of 10^{-4}

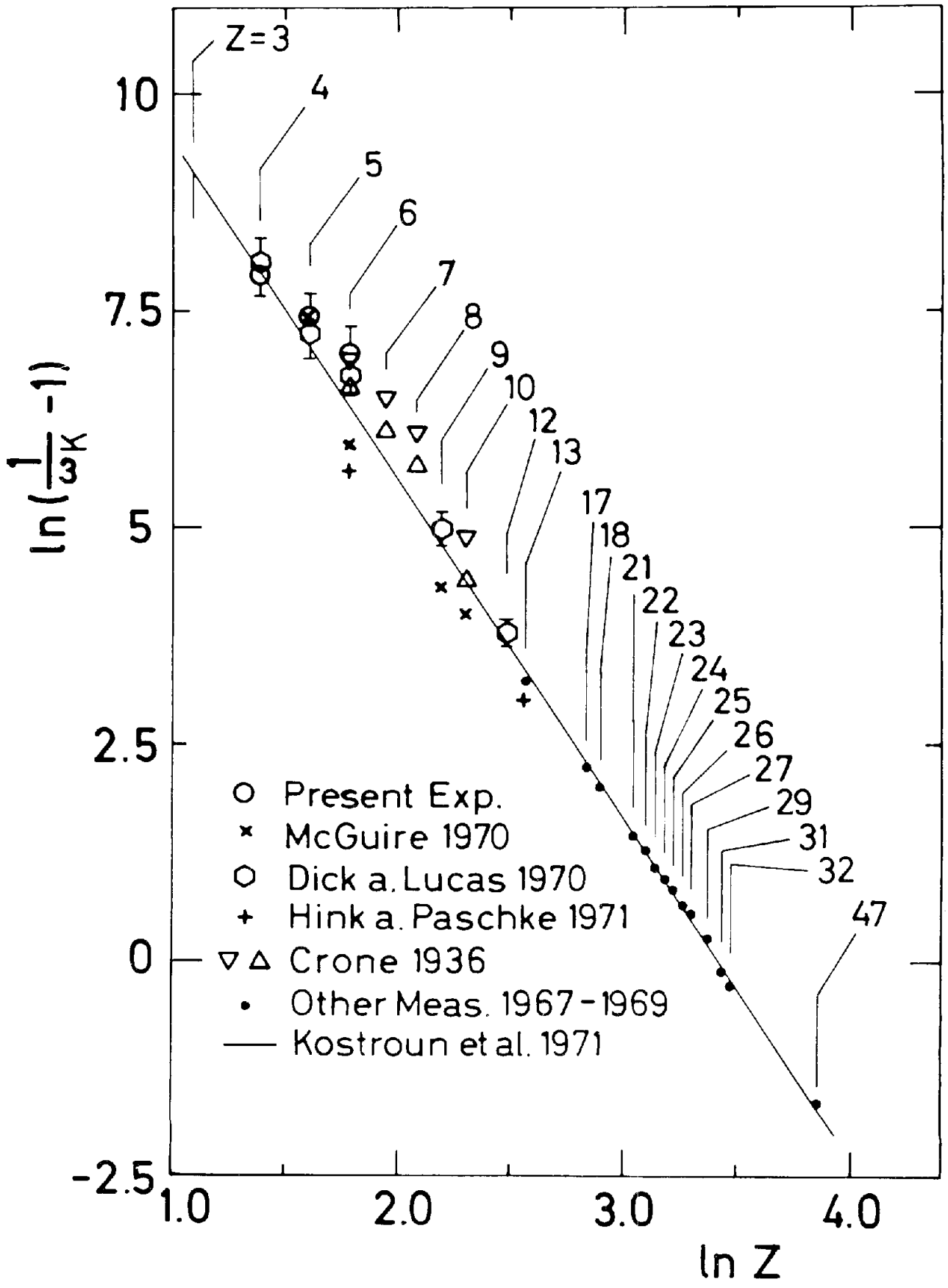
	Beryllium	Boron	Carbon
McGuire, Ref. 1 (Theory)		5.6	26
Present work	3.6 ±30 %	5.7 ±30 %	8.8 ±30 %
Dick and Lucas, Ref. 2	3.04 ±20 %	7.10 ±40 %	11.3 ±20 %
Hink and Paschke, Ref. 3			35 ±10 %
Crone, Ref. 15			9 ±45 %

Figure Caption

Fig. 1 Plot of the K-shell fluorescence yield ω_K after Byrne and Howarth (see Ref. 16), for Be to C (present work) and Be to Ag (see Refs. 1 to 3, 15, 18 to 23). Straight line: Approximation after Kostroun et al. (see Ref. 17).

References

1. E.J. McGuire, Phys. Rev. A 2, 273 (1970)
2. C.E. Dick and A.C. Lucas, Phys. Rev. A 2, 580 (1970)
3. W. Hink and H. Paschke, Phys. Rev. A 4, 507 (1971)
4. A.J. Campbell, Proc. Roy. Soc. A 274, 319 (1963)
5. R. Haensel and C. Kunz, Z. Angew. Phys. 23, 276 (1967)
6. R.P. Godwin, Springer Tracts Mod. Phys. 51, 1 (1969)
7. R. Haensel and B. Sonntag, J. Appl. Phys. 38, 3031 (1967)
8. D. Lemke and D. Labs, Appl. Opt. 6, 1043 (1967)
9. B.L. Henke, R. White and B. Lundberg, J. Appl. Phys. 28, 98 (1957)
10. V.A. Fomichev and I.I. Zhukova, Opt. Spectr. 24, 147 (1968)
11. R. Haensel, G. Keitel, B. Sonntag, C. Kunz and P. Schreiber, Phys. Stat. Sol. (a) 2, 85 (1970)
12. K. Feser, J. Müller, G. Wiech and A. Faessler, DESY 70/59 (1970), to be published in J. Physique 32 - C4 (1971)
13. K. Feser, Thesis Universität München 1971
14. K. Feser, Rev. Sci. Instr. 42, 888 (1971)
15. W. Crone, Ann. Physik 27, 405 (1936)
16. J. Byrne and N. Howarth, J. Phys. B 3, 280 (1970)
17. V.O. Kostroun, M.H. Chen and B. Crasemann, Phys. Rev. A 3, 533 (1971)
18. L.E. Bailey and J.B. Swedlund, Phys. Rev. 158, 6 (1967)
19. W. Bambynek, Z. Physik 206, 66 (1967)
20. W. Bambynek and D. Reher, Z. Physik 214, 374 (1968)
21. H.U. Freund, H. Genz, J.B. Siberts and R.W. Fink, Nucl. Phys. A 138, 200 (1969)
22. J. Pahor, A. Kodre, M. Hribar and A. Moljk, Z. Physik 221, 490 (1969)
23. C. Foin, A. Gidson and J. Oms, Nucl. Phys. A 113, 241 (1968)


Z=3
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29
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32
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7.5
5
2.5
0
-2.5
1.0
2.0
3.0
4.0
ln Z
ln(1/3K -1)
Present Exp.
McGuire 1970
Dick a. Lucas 1970
Hink a. Paschke 1971
Crone 1936
Other Meas. 1967-1969
Kostroun et al. 1971

Fig.1