Experimental Study of the Absorption-Formula of X-Rays, Part II

By

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(Received August 23, 1930)

The experimental method was similar to that described in the previous paper[1] by the authors, and the description will not be given here. The results of the investigation together with the former ones[2] are shown in the annexed tables. The mass absorption coefficient of hydrogen was assumed to be 0.466 for the *Mo* K_α line and 0.440 for the *Mo* K_β line, these figures being taken from the data of Olson, Dershem and Storch.[3] For the mass scattering coefficients of several elements, $\frac{\sigma}{\rho}$, the same numerical values are assumed as in the previous paper, and are shown in the last column of Table II. Fig. 1 shows the relation of the true gram atomic absorption coefficient $\frac{\tau}{\rho}\cdot A$ and the atomic number Z, and Fig. 2 that of the $\frac{\tau}{\rho}\cdot A$ and the wave-length λ for the elements which were examined in the form of metallic foil.

From Fig. 1 the following relations were found

(1) in the case of the K series ($\lambda < \lambda_{K\text{-absorption edge}}$)

$$\frac{\tau}{\rho}\cdot A = cZ^{3.99} \qquad \text{for } Mo\ K_\beta \text{ (0.629 Å. u.)},$$

$$\frac{\tau}{\rho}\cdot A = cZ^{3.88} \qquad \text{for } Mo\ K_\alpha \text{ (0.709 Å. u.)},$$

1. These Memoirs; **10**, 311 (1927).

2. It has been found that in the foregoing experiment there was a considerable error in the estimation of the concentration of $HgCl_2$. The experiment was carried out again throughout for *Mo* K_α very carefully and the corrected results are given in Table I. B.

3. Phys. Rev., **21**, 36 (1923).

Fig. 1

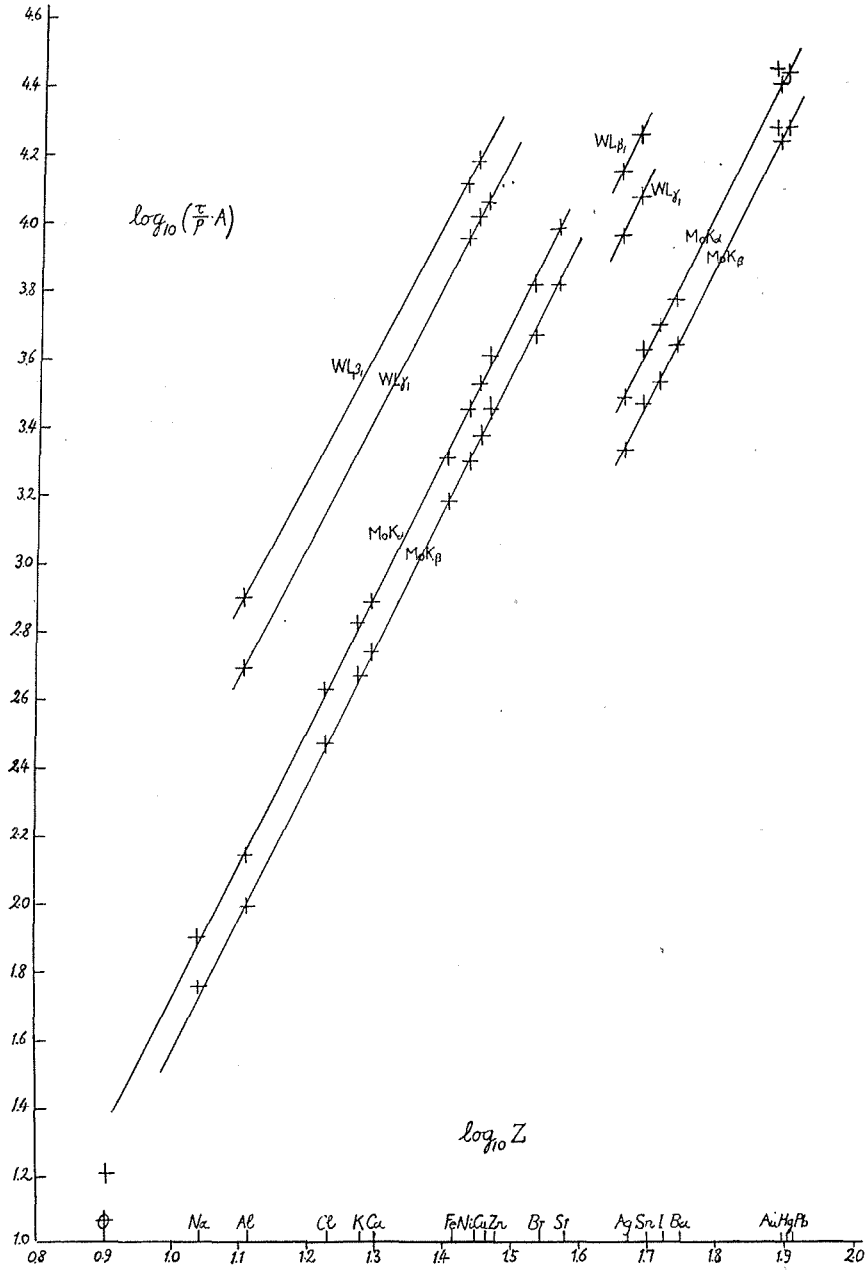
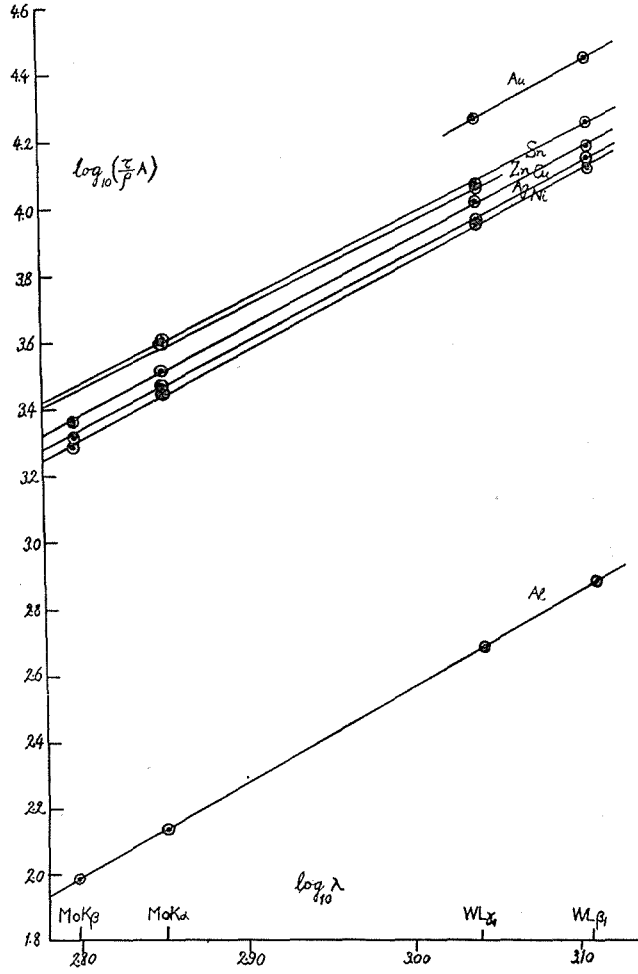

$\log_{10}\left(\frac{\tau}{P}\cdot A\right)$
$\log_{10} Z$
WL_{β_1}
WL_{γ_1}
MoK_α
MoK_β
Na Al Cl K Ca Fe Ni Cu Zn Br Sr Ag Sn I Ba Au Hg Pb

Fig. 2



$$\frac{\tau}{\rho}\cdot A = cZ^{3.75} \qquad \text{for } W\,L_{\gamma_1}\ (1.096\ \text{Å. u.}),$$

$$\frac{\tau}{\rho}\cdot A = cZ^{3.66} \qquad \text{for } W\,L_{\beta_1}\ (1.279\ \text{Å. u.}),$$

and

(2) in the case of the L series ($\lambda_K < \lambda < \lambda_{L_1}$)

$$\frac{\tau}{\rho}\cdot A = cZ^{3.88} \qquad \text{for } Mo\,K_\beta\ (0.629\ \text{Å. u.})$$

$$\frac{\tau}{\rho}\cdot A = cZ^{3.88} \qquad \text{for } Mo\,K_\alpha\ (0.709\ \text{Å. u.})$$

$$\frac{\tau}{\rho}\cdot A = cZ^{4.0} \qquad \text{for } WL_{\gamma_1}{}^{1}(1.096\ \text{Å. u.})$$

$$\frac{\tau}{\rho}\cdot A = cZ^{4.0} \qquad \text{for } WL_{\beta_1}{}^{1}(1.279\ \text{Å. u.})$$

Next, from Fig. 2 we obtain the formula
(1) in the case of the K series

$$\frac{\tau}{\rho}\cdot A = c'\lambda^{2.93} \qquad \text{for } Al,\ Z=13,$$

$$\frac{\tau}{\rho}\cdot A = c'\lambda^{2.63} \qquad \text{for } Ni,\ Z=28,$$

$$\frac{\tau}{\rho}\cdot A = c'\lambda^{2.60} \qquad \text{for } Cu,\ Z=29,$$

(2) in the case of the L series

$$\frac{\tau}{\rho}\cdot A = c'\lambda^{2.59} \qquad \text{for } Ag,\ Z=47,$$

$$\frac{\tau}{\rho}\cdot A = c'\lambda^{2.48} \qquad \text{for } Sn,\ Z=50,$$

and
(3) in the case of the M series

$$\frac{\tau}{\rho}\cdot A = c'\lambda^{2.30} \qquad \text{for } Au,\ Z=79,$$

From the study of the data thus obtained it seems to us right to conclude that the fluorescent absorption of X-rays as a function of λ and Z does not obey such a simple law as given by

$$\frac{\tau}{\rho}\cdot A = c\lambda^{p}Z^{q}$$

in which c, p and q remain constant, but that it must be connected by a more complex relation.[2] Also, if it is to be expressed by the above formula, the constancy of p and q should hold only in a restricted region,[3] and, in the general case, they should somewhat depend on λ and Z. In the region investigated here, p and q are nearly, but certainly less than, 3 and 4 respectively, and it is seen that when

1. As these were obtained from only two elements *Ag* and *Sn*, not much stress can be laid on them.

2. See S. J. M. Allen: Phys. Rev., **28**, 907 (1926).

3. Perhaps for light elements or with somewhat hard X-rays. For example the absorption coefficient of *Al* seems to be expressed very well by the simple law $\frac{\tau}{\rho}\cdot A = c^{2.93}$ in a fairly wide region.

λ becomes larger in comparison with the critical absorption wave-length the index-number of Z becomes smaller, and when Z increases the index-number of λ decreases.

Table I. A.

Direct data of measurement with the $MoK\tilde{\beta}_{1,2}$ line (0.629 Å. u.)

Absorber	$\frac{area}{mass}\left(\frac{A}{m}\right)$	Intensity Ratio(I_0/I)	Mass Absorption Coefficient (μ/ρ)
Al	3.949	2.563	3.72
Ni	21.78	4.611	33.29
Cu	37.05	2.668	36.36
Zn	41.96	2.746	42.39
Ag	20.99	2.562	19.75
Sn	36.36	1.958	24.43

Absorber	Concentration %	Density (ρ) at Temperature (t_0c)	Intensity Ratio (I_0/I)	Mass Absorption Coefficient (μ/ρ)
H_2O		0.9968(26°. c)	1.380	0.828
HNO_3	12.35	1.0687(27°. c)	1.416	0.881
HCl	24.69	1.1230(18°. c)	3.171	8.147
NaCl	24.40	1.1841(17.4°c)	2.654	6.097
KCl	8.10	1.0510(17.0°c)	1.916	10.190
$CaCl_2$	8.12	1.0682(17.1°c)	1.941	10.236
$FeCl_3$	5.87	1.0478(19.6°c)	1.953	14.626
BrK	4.67	1.0331(17.9°c)	3.030	42.012
$Sr(NO_3)_2$	4.17	1.0328(18.3°c)	2.298	30.507
IK	6.00	1.0442(20.2°c)	2.405	22.942
$BaCl_2$	5.97	1.0537(19.2°c)	2.440	23.316
$HgCl_2$	2.54	1.0197(18.0°c)	2.610	63.203
$Pb(NO_3)_2$	2.37	1.0203(16.5°c)	2.332	55.675

Table I. B.

Direct data of measurement with the $MoK_{\alpha_{1,2}}$ line (0.709 Å. u.)

Absorber	%	ρ at t°c.	I_0/I	μ/ρ
$BaCl_2$	4.05	1.0355(18.5°c.)	2.557	31.671
$HgCl_2$	2.00	1.0153(17.0°c.)	3.176	92.708
$Pb(NO_3)_2$	1.41	1.0113(18.0°c.)	2.374	79.530

Table I. C.

Direct data of measurement with the WL_{γ_1} line (1.096 Å. u.)

Absorber	A/m	I_0/I	μ/ρ
Al	22.22	2.261	18.13
Ni	79.05	6.478	147.70
Cu	68.00	10.279	158.44
Zn	134.48	3.516	169.08
Ag	60.59	3.867	81.95
Sn	85.39	3.096	96.50
Au	96.47	2.591	91.84

Table I. D.

Direct data of measurement with the WL_{β_1} line (1.279 Å. u.)

Absorber	A/m	I_0/I	μ/ρ
Al	22.22	3.669	28.88
Ni	79.05	15.04	214.28
Cu	68.00	29.39	229.88
Ag	60.59	7.936	125.50
Sn	85.39	5.537	146.14
Au	96.47	4.136	136.96

Table II.

True mass absorption coefficient. $\tau/\rho=\mu/\rho-\sigma/\rho$.

Element.	Line.	MoK_β	MoK_α	WL_{γ_1}	WL_{β_1}	(σ/ρ)assumed.
8	O	0.72	1.0			0.16
11	Na	2.45	3.41			0.15
13	Al	3.57	5.06	17.98	28.73	0.15
17	Cl	8.21	11.76			0.16
19	K	11.67	16.70			0.17
20	Ca	13.38	18.86			0.17
26	Fe	26.35	35.72			0.20
28	Ni	33.08	46.95	147.49	214.07	0.21
29	Cu	36.15	51.22	158.23	229.67	0.21
30	Zn	42.17	60.02	168.86		0.22
35	Br	56.53	79.23			0.24
38	Sr	72.16	105.14			0.26
47	Ag	19.17	27.30	81.37	124.92	0.58
50	Sn	23.80	34.22	95.87	145.51	0.63
53	I	25.71	37.80			0.65
56	Ba	30.35	41.19			0.68
79	Au			90.92	136.04	0.92
80	Hg	81.66	120.34			0.93
82	Pb	87.52	125.52			0.95