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Theoretical Calculation of Fluorescent X-Ray Intensities of Nickel-Iron-Chromium Ternary Alloys

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The fluorescent X-ray intensities of nickel-iron-chromium alloys which cover the entire range of the system are obtained by theoretical calculation. The calculated results show that the iron fluorescent X-ray intensity is much affected by the amount of the other elements, while the nickel and chromium fluorescent X-ray intensities are less affected. The calculated results agree with the experimental results; their difference is less than 1%. In the calculations, the intensities of the primary, the secondary, and the tertiary fluorescent X-rays are obtained, where the primary fluorescent X-rays are defined as being excited by incident X-rays only; the secondary fluorescent X-rays as excited by the primary, and the tertiary fluorescent X-rays, as excited by the secondary fluorescent X-rays. The calculated results show that the secondary fluorescent X-rays are significant, but the tertiary fluorescent X-rays form only a small percentage of the total fluorescent X-rays at most.

In a previous work,[1] the present authors have reported the theoretical formulas which give the fluorescent X-ray intensities in general. These formulas gave the intensities of the primary, the secondary, and the tertiary fluorescent X-rays, which are defined as follows. The primary fluorescent X-rays are X-rays emitted from atoms excited by the incident X-rays only. The secondary fluorescent X-rays are emitted from atoms excited by the primary fluorescent X-rays from the coexistent element, and the tertiary fluorescent X-rays are emitted by the secondary fluorescent X-rays. In the previous work, the theoretical equations were given, the theoretical and the experimental results were compared mainly on binary nickel-iron and iron-chromium alloys, and the primary and the secondary fluorescent X-ray intensities were discussed.

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[1] T. Shiraiwa and N. Fujino, *Japan. J. of Appl. Phys.*, **5**, 886 (1966).

In the present paper, the calculations are applied to nickel-iron-chromium ternary alloys, where each component is varied from 0 to 100%. This is a suitable case for studying the primary, the secondary, and the tertiary fluorescent X-rays. Nickel fluorescent X-rays are the primary fluorescent X-rays only; iron fluorescent X-rays consist of both primary and secondary, and chromium fluorescent X-rays consist of primary, secondary, and tertiary.

Calculation

The theroetical equations for the calculation of the fluorescent X-ray intensities derived in the previous report[1] are as follows.

Primary Fluorescent X-Ray Intensity.

$$I_1(ip)=\frac{1}{\sin\Psi}\int_{\lambda_m}^{\lambda^i{}_e}\frac{Q_{ip}(\lambda)I_0(\lambda)}{\dfrac{\mu(\lambda)}{\rho}\Big/\sin\Phi+\dfrac{\mu(ip)}{\rho}\Big/\sin\Psi}\,\mathrm{d}\lambda\,,$$

$$\frac{\mu(\lambda)}{\rho}=\sum_i\frac{\mu_i(\lambda)}{\rho_i}W_i\,,\qquad Q_{ip}(\lambda)=\frac{\mu_i(\lambda)}{\rho_i}W_iK_i\omega_iR^i{}_p\,.$$

Secondary Fluorescent X-Ray Intensity.

$$I_2(ip)=\frac{1}{2\sin\Psi}\sum_{jq}\int_{\lambda_m}^{\lambda^j{}_e}\frac{Q_{jq}(\lambda)Q_{ip}(jq)I_0(\lambda)}{\dfrac{\mu(\lambda)}{\rho}\Big/\sin\Phi+\dfrac{\mu(ip)}{\rho}\Big/\sin\Psi}$$

$$\times\left\{\frac{\sin\Psi}{\dfrac{\mu(ip)}{\rho}}\log\left[1+\frac{\dfrac{\mu(ip)}{\rho}\Big/\sin\Psi}{\dfrac{\mu(jq)}{\rho}}\right]+\frac{\sin\Phi}{\dfrac{\mu(\lambda)}{\rho}}\log\left[1+\frac{\dfrac{\mu(\lambda)}{\rho}\Big/\sin\Phi}{\dfrac{\mu(jq)}{\rho}}\right]\right\}\mathrm{d}\lambda\,.$$

Tertiary Fluorescent X-Ray Intensity.

$$I_3(ip)=\frac{1}{4\sin\Psi}\int_{\lambda_m}^{\lambda^k{}_e}\sum_{kr}\sum_{jq}\frac{Q_{kr}(\lambda)Q_{jq}(kr)Q_{ip}(jq)I_0(\lambda)}{A(\lambda)+D(ip)}$$

$$\times\left[\frac{1}{A^2(\lambda)}\log\frac{B(kr)+A(\lambda)}{B(kr)}\log\frac{C(jq)+A(\lambda)}{C(jq)}\right.$$

$$+\frac{1}{A(\lambda)D(ip)}\log\frac{B(kr)+A(\lambda)}{B(kr)}\log\frac{C(jq)+D(ip)}{C(jq)}$$

$$+\frac{1}{D^2(ip)}\log\frac{B(kr)+D(ip)}{B(kr)}\log\frac{C(jq)+D(ip)}{C(jq)}$$

$$+\left(\frac{1}{A(\lambda)}+\frac{1}{D(ip)}\right)\left(\frac{1}{C(jq)}\log\frac{B(kr)+C(jq)}{B(kr)}+\frac{1}{B(kr)}\log\frac{B(kr)+C(jq)}{C(jq)}\right)$$

$$-\frac{1}{A(\lambda)}\int_0^{B(kr)/C(jq)}\frac{1}{A(\lambda)t+B(kr)}\log\frac{1+t}{t}\,\mathrm{d}t$$

$$\left.-\frac{1}{D(ip)}\int_0^{C(jq)/B(kr)}\frac{1}{D(ip)t+C(jq)}\log\frac{1+t}{t}\,\mathrm{d}t\right]\mathrm{d}\lambda$$

$$A(\lambda)=\frac{1}{\sin\Phi}\cdot\frac{\mu(\lambda)}{\rho}\,,\qquad Q_{kr}(\lambda)=\frac{\mu_k(\lambda)}{\rho_k}W_k\omega_kR^k{}_rK_k\,,$$

$$B(kr)=\frac{\mu(kr)}{\rho}\,,$$

$$C(jq)=\frac{\mu(jq)}{\rho}\,,\qquad Q_{jq}(kr)=\frac{\mu_j(kr)}{\rho_j}W_j\omega_jR^j{}_qK_j\,,$$

$$D(ip)=\frac{1}{\sin\Psi}\cdot\frac{\mu(ip)}{\rho}\,,\qquad Q_{ip}(jq)=\frac{\mu_i(jq)}{\rho_i}W_i\omega_iR^i{}_pK_i\,.$$

Explanations of the notations in the equations are given in Table 1.

The values of the mass-absorption coefficients are taken from the "International Tables for X-ray Crystallography,"[2] and the fluorescent yield, ω_i

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[2] The International Union of Crystallography, "International Tables for X-ray Crystallography," Vol. III, Kynoch Press, Birmingham (1962).

TABLE 1. NOTATIONS USED IN EQUATIONS

Φ:	The angle made by the incident beam with the sample surface.
Ψ:	The angle made by the emergent beam with the sample surface.
$I_0(\lambda)$:	The intensity of the incident X-rays of wavelength λ.
I_1:	The intensity of the primary fluorescent X-Rays (emitted by the incident X-rays).
I_2:	The intensity of the secondary fluorescent X-rays (emitted by the primary fluorescent X-rays).
I_3:	The intensity of the tertiary fluorescent X-rays (emitted by the secondary fluorescent X-rays).
$I(ip)$:	The intensity of the X-ray of p-line emitted from element i, where i refers to the element and p refers to the spectral line.
$\mu(\lambda)$:	The linear absorption coefficient of the specimen for the X-ray of wavelength λ.
$\mu(ip)$:	The linear absorption coefficient of the specimen for the characteristic X-ray, p-line of the element i.
$\mu_i(\lambda)$:	The linear absorption coefficient of the element i for the X-ray of wavelength λ.
$\mu_j(ip)$:	The linear absorption coefficient of element j for the characteristic X-ray, p-line of element i.
ρ:	The density of the specimen.
ρ_i:	The density of element i.
W_i:	The weight fraction of element i in the specimen.
ω_i:	Fluorescent yield of element i.
$R^i{}_p$:	The intensity fraction of the p-line, in the characteristic X-ray series which p-line belongs to.
K_i:	The absorption jump of element i.
λ_m:	The minimum wavelength of exciting X-rays.
$\lambda^i{}_e$:	The wavelength of the absorption edge of element i.

the intensity fraction, $R^i{}_p$, and the absorption jumping ratio, K_i are taken from the monograph of Compton and Allison.[3] The intensity distribution of incident continuous X-rays has been shown in the previous report.[1]

The equations are computed by means of a NEAC 2203 computor; the program can calculate the intensities of the primary, the secondary, and the tertiary fluorescent X-rays for ten-element systems. The time required to compute a component is 25, 40, and 1200 sec for the primary, the secondary and the tertiary fluorescent X-ray intensities respectively.

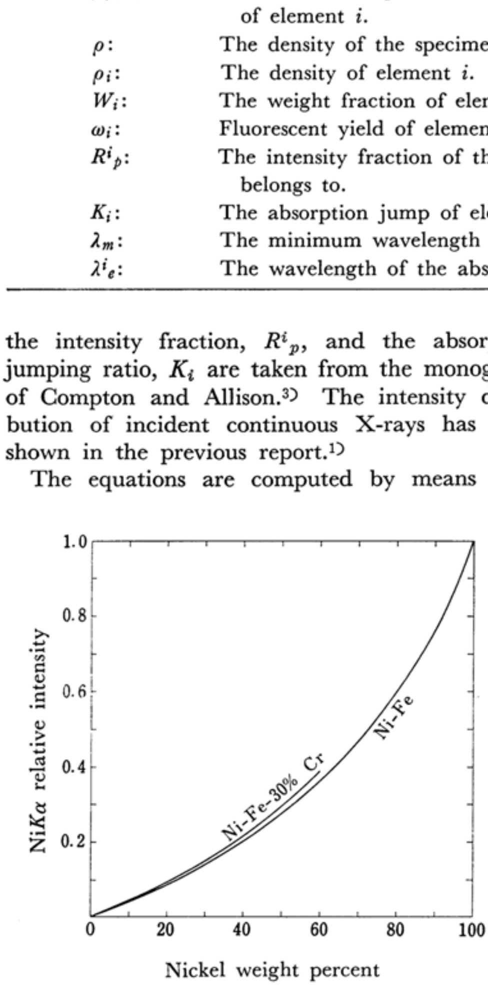

Fig. 1. Theoretical intensity of Ni$K\alpha$ fluorescent X-rays from Ni-Fe binary alloys and Ni-Fe-30%Cr ternary alloys, using tungsten target operated 30 K. V. P. full-wave rectifier.

Tables 2 and 3 give the calculated results. In Table 2, the fluorescent intensity of each sample is expressed in terms of its ratio to that of a pure element. In table 3, the relative values, normalized

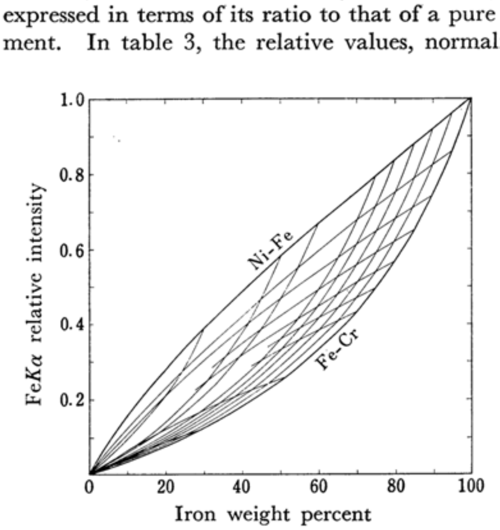

Fig. 2(a). Theoretical intensity of Fe$K\alpha$ fluorescent X-rays from Ni-Fe-Cr ternary alloys, conditions are equal to the case of Fig. 1.

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3) A. H. Compton and S. A. Allison: "X-rays in Theory and Experiment," 2nd ed., D. Van Nostrand Co. New York (1935).

TABLE 2. RELATIVE INTENSITY OF FLUORESCENT X-RAYS TO THE PURE ELEMENT

Composition, %			Nickel fluorescent X-rays	Iron fluorescent X-rays			Chromium fluorescent X-rays				
Ni	Fe	Cr	I_1(Ni$K\alpha$)	I_1(Fe$K\alpha$)	I_2(Fe$K\alpha$) by NiK	$\sum I$(Fe$K\alpha$)	I_1(Cr$K\alpha$)	I_2(Cr$K\alpha$) by NiK	I_2(Cr$K\alpha$) by FeK	I_3(Cr$K\alpha$)	$\sum I$(Cr$K\alpha$)
0	95	5	—	0.860	—	0.860	0.054	—	0.028	—	0.082
0	90	10	—	0.745	—	0.745	0.107	—	0.046	—	0.154
0	85	15	—	0.650	—	0.650	0.158	—	0.060	—	0.218
0	80	20	—	0.568	—	0.568	0.209	—	0.070	—	0.278
0	75	25	—	0.498	—	0.498	0.258	—	0.075	—	0.333
0	70	30	—	0.436	—	0.436	0.307	—	0.080	—	0.387
0	50	50	—	0.251	—	0.251	0.493	—	0.083	—	0.576
0	30	70	—	0.126	—	0.126	0.688	—	0.058	—	0.747
0	10	90	—	0.035	—	0.035	0.895	—	0.022	—	0.917
5	95	0	0.020	0.946	0.013	0.960	—	—	—	—	—
5	90	5	0.020	0.812	0.011	0.823	0.054	0.000	0.025	0.000^{4}	0.080
5	85	10	0.020	0.702	0.010	0.711	0.106	0.001	0.043	0.000^{6}	0.150
5	80	15	0.020	0.610	0.008	0.618	0.157	0.001	0.055	0.000^{8}	0.214
5	75	20	0.020	0.532	0.007	0.538	0.207	0.002	0.064	0.001^{0}	0.273
5	70	25	0.020	0.464	0.006	0.470	0.256	0.002	0.069	0.001^{1}	0.328
5	65	30	0.021	0.404	0.005	0.409	0.304	0.003	0.072	0.001^{1}	0.381
5	45	50	0.021	0.226	0.003	0.228	0.496	0.005	0.068	0.001^{0}	0.571
5	20	75	0.022	0.081	0.001	0.082	0.742	0.009	0.038	0.000^{6}	0.790
10	90	0	0.040	0.893	0.026	0.919	—	—	—	—	—
10	85	5	0.041	0.764	0.022	0.786	0.054	0.001	0.023	0.000^{7}	0.078
10	80	10	0.041	0.659	0.018	0.677	0.105	0.002	0.039	0.001^{2}	0.148
10	75	15	0.041	0.571	0.016	0.586	0.156	0.003	0.051	0.001^{5}	0.211
10	70	20	0.042	0.495	0.013	0.509	0.205	0.004	0.058	0.001^{7}	0.269
10	65	25	0.042	0.430	0.011	0.441	0.254	0.005	0.063	0.001^{9}	0.324
10	60	30	0.043	0.373	0.010	0.383	0.302	0.006	0.066	0.002^{0}	0.376
10	40	50	0.044	0.200	0.005	0.205	0.492	0.011	0.060	0.001^{9}	0.565
10	10	80	0.047	0.039	0.001	0.040	0.787	0.020	0.020	0.000^{6}	0.827
15	85	0	0.063	0.838	0.038	0.876	—	—	—	—	—
15	80	5	0.063	0.717	0.031	0.749	0.053	0.001	0.022	0.001^{0}	0.077
15	75	10	0.064	0.617	0.026	0.643	0.104	0.003	0.036	0.001^{7}	0.145
15	70	15	0.064	0.532	0.022	0.558	0.155	0.004	0.047	0.002^{1}	0.208
15	65	20	0.065	0.459	0.019	0.478	0.204	0.006	0.054	0.002^{5}	0.265
15	60	25	0.066	0.397	0.016	0.413	0.252	0.007	0.058	0.002^{7}	0.320
15	55	30	0.066	0.342	0.014	0.355	0.300	0.009	0.060	0.002^{8}	0.371
15	35	50	0.069	0.175	0.007	0.182	0.489	0.016	0.052	0.002^{5}	0.560
20	80	0	0.087	0.787	0.048	0.835	—	—	—	—	—
20	75	5	0.087	0.671	0.040	0.711	0.053	0.002	0.020	0.001^{2}	0.076
20	70	10	0.088	0.575	0.034	0.608	0.104	0.004	0.034	0.002^{1}	0.143
20	65	15	0.089	0.493	0.029	0.522	0.153	0.006	0.043	0.002^{7}	0.205
20	60	20	0.089	0.424	0.024	0.448	0.202	0.008	0.049	0.003^{1}	0.262
20	55	25	0.090	0.363	0.020	0.384	0.250	0.010	0.052	0.003^{3}	0.316
20	50	30	0.091	0.310	0.017	0.328	0.297	0.012	0.054	0.003^{4}	0.367
20	30	50	0.095	0.150	0.008	0.158	0.486	0.022	0.044	0.002^{9}	0.555
25	75	0	0.112	0.736	0.057	0.793	—	—	—	—	—
25	70	5	0.113	0.625	0.048	0.674	0.052	0.002	0.018	0.001^{5}	0.074
25	65	10	0.114	0.533	0.040	0.573	0.103	0.005	0.031	0.002^{5}	0.141
25	60	15	0.115	0.455	0.034	0.489	0.152	0.007	0.039	0.003^{2}	0.202
25	55	20	0.116	0.388	0.029	0.417	0.200	0.010	0.044	0.003^{8}	0.259
25	50	25	0.117	0.330	0.024	0.354	0.248	0.013	0.047	0.003^{9}	0.312
25	45	30	0.118	0.279	0.020	0.299	0.295	0.016	0.048	0.004^{0}	0.367
25	25	50	0.123	0.125	0.009	0.134	0.483	0.029	0.037	0.003^{1}	0.555

TABLE 2 (Continued)

Composition, %			Nickel fluorescent X-rays I_1(Ni$K\alpha$)	Iron fluorescent X-rays			Chromium fluorescent X-rays				
Ni	Fe	Cr		I_1(Fe$K\alpha$)	I_2(Fe$K\alpha$) by NiK	$\sum I$(Fe$K\alpha$)	I_1(Cr$K\alpha$)	I_2(Cr$K\alpha$) by NiK	I_2(Cr$K\alpha$) by FeK	I_3(Cr$K\alpha$)	$\sum I$(Cr$K\alpha$)
40	60	0	0.201	0.591	0.077	0.668	—	—	—	—	—
40	50	10	0.205	0.410	0.053	0.463	0.101	0.009	0.023	0.003^{3}	0.135
40	40	20	0.209	0.283	0.037	0.319	0.197	0.018	0.028	0.004^{6}	0.247
40	30	30	0.213	0.187	0.024	0.210	0.290	0.028	0.031	0.004^{6}	0.254
40	10	50	0.223	0.050	0.006	0.057	0.476	0.051	0.014	0.002^{2}	0.543
50	40	10	0.279	0.329	0.044	0.372	0.099	0.011	0.018	0.003^{5}	0.132
50	30	20	0.285	0.213	0.028	0.241	0.194	0.024	0.023	0.004^{6}	0.246
50	20	30	0.292	0.125	0.021	0.146	0.287	0.038	0.021	0.004^{1}	0.350
50	10	40	0.299	0.056	0.009	0.065	0.380	0.052	0.012	0.002^{5}	0.447
70	30	0	0.463	0.310	0.078	0.387	—	—	—	—	—
70	20	10	0.478	0.167	0.043	0.210	0.098	0.019	0.009	0.002^{9}	0.129
70	10	20	0.491	0.072	0.021	0.093	0.192	0.040	0.008	0.002^{6}	0.242
80	10	10	0.615	0.085	0.033	0.118	0.097	0.025	0.005	0.001^{9}	0.128
90	5	5	0.779	0.047	0.024	0.071	0.049	0.016	0.001	0.000^{7}	0.066

TABLE 3. INTENSITY RATIOS OF THE PRIMARY, SECONDARY AND TERTIARY FLUORESCENT X-RAYS FROM Ni-Fe-Cr ALLOYS TO THE TOTAL ONE

Composition, %			Iron fluorescent X-rays		Chromium fluorescent X-rays		
Ni	Fe	Cr	I_1(Fe$K\alpha$)	I_2(Fe$K\alpha$)	I_1(Cr$K\alpha$)	I_2(Cr$K\alpha$)	I_3(Cr$K\alpha$)
0	95	5	100.00	—	65.85	34.15	—
0	90	10	100.00	—	67.53	32.47	—
0	85	15	100.00	—	72.48	27.52	—
0	80	20	100.00	—	75.18	24.82	—
0	75	25	100.00	—	77.48	22.52	—
0	70	30	100.00	—	79.33	20.67	—
0	50	50	100.00	—	85.59	14.41	—
0	30	70	100.00	—	92.10	7.90	—
0	10	90	100.00	—	97.60	2.40	—
5	95	0	98.62	1.38	—	—	—
5	90	5	98.64	1.36	67.71	31.79	0.50
5	85	10	98.66	1.34	70.68	28.92	0.40
5	80	15	98.69	1.31	73.36	26.28	0.37
5	75	20	98.71	1.29	75.73	23.90	0.37
5	70	25	98.73	1.27	77.94	21.72	0.34
5	65	30	98.75	1.25	79.95	19.76	0.29
5	45	50	98.77	1.23	86.94	12.88	0.18
5	20	75	98.80	1.20	93.97	5.95	0.08
10	90	0	97.18	2.82	—	—	—
10	85	5	97.23	2.77	68.37	30.74	0.89
10	80	10	97.28	2.72	71.31	27.88	0.81
10	75	15	97.34	2.66	73.91	25.38	0.71
10	70	20	97.38	2.62	76.25	23.12	0.63
10	65	25	97.42	2.58	78.38	21.00	0.59
10	60	30	97.44	2.56	80.35	19.12	0.53
10	40	50	97.47	2.53	87.14	12.53	0.34
10	10	80	97.50	2.50	95.19	4.74	0.07

TABLE 3 (Continued)

Composition, %			Iron fluorescent X-rays		Chromium fluorescent X-rays		
Ni	Fe	Cr	I_1(Fe$K\alpha$)	I_2(Fe$K\alpha$)	I_1(Cr$K\alpha$)	I_2(Cr$K\alpha$)	I_3(Cr$K\alpha$)
15	85	0	95.68	4.32	—	—	—
15	80	5	95.81	4.19	68.96	29.74	1.30
15	75	10	95.89	4.11	71.85	26.98	1.17
15	70	15	95.98	4.02	74.46	24.53	1.01
15	65	20	96.03	3.97	76.71	22.36	0.94
15	60	25	96.07	3.93	78.79	20.37	0.84
15	55	30	96.12	3.88	80.73	18.52	0.75
15	35	50	96.27	3.73	87.34	12.22	0.45
20	80	0	94.25	5.75	—	—	—
20	75	5	94.33	5.65	69.58	28.83	1.59
20	70	10	94.44	5.56	72.43	26.10	1.47
20	65	15	94.54	5.46	74.91	23.77	1.32
20	60	20	94.62	5.38	77.15	21.67	1.18
20	55	25	94.68	5.32	79.21	19.75	1.05
20	50	30	94.75	5.25	81.10	17.98	0.93
20	30	50	94.95	5.05	88.08	11.42	0.50
25	75	0	92.81	7.19	—	—	—
25	70	5	92.85	7.15	70.16	27.83	2.02
25	65	10	92.95	7.05	72.89	25.34	1.77
25	60	15	93.06	6.94	75.36	23.06	1.59
25	55	20	93.16	6.84	77.49	21.04	1.47
25	50	25	93.25	6.75	79.54	19.21	1.25
25	45	30	93.32	6.68	81.37	17.52	1.10
25	25	50	93.51	6.49	87.60	11.84	0.56
40	60	0	88.45	11.55	—	—	—
40	50	10	88.49	11.51	74.33	23.23	2.44
40	40	20	88.51	11.49	79.72	18.42	1.87
40	30	30	88.77	11.23	82.05	16.65	1.30
40	10	50	89.00	11.00	87.61	11.98	0.41
50	40	10	88.12	11.88	75.09	22.26	2.65
50	30	20	88.37	11.63	78.99	19.14	1.87
50	20	30	85.35	14.65	82.23	16.60	1.17
50	10	40	85.56	14.44	84.94	14.49	0.56
70	30	0	80.43	19.57	—	—	—
70	20	10	79.46	20.54	75.88	21.87	2.26
70	10	20	77.20	22.80	79.11	19.82	1.07
80	10	10	72.02	27.98	75.70	22.82	1.48
90	5	5	66.20	33.80	73.49	25.45	1.05

by the total fluorescent X-ray intensity, are given.

Figures 1, 2, and 3 show the fluorescent X-ray intensities of nickel, iron, and chromium respectively *versus* their weight fraction.

The intensity of Ni$K\alpha$ fluorescent X-rays is scarcely affected by the other components, iron and chromium. This is because the absorption coefficient of chromium is nearly equal to that of iron for Ni$K\alpha$ and the incident X-rays. For Fe$K\alpha$ fluorescent X-rays, the absorption coefficient of nickel is different from that of chromium, so the intensity of Fe$K\alpha$ fluorescent X-rays is much affected by the ratio of nickel to chromium. For Cr$K\alpha$ fluorescent X-rays, the situation is similar to the case of Ni$K\alpha$, so the intensity of Cr$K\alpha$ is less affected by the other components.

The extents of the enhancement effect are shown in Tables 2 and 3. The secondary fluorescent X-ray intensity reaches several tens of the percentage of the total fluorescent X-ray intensity, so it should not be neglected in calculations. The tertiary fluorescent X-ray intensity is, however, only a small percentage of the total intensity, so it can be neglected if accuracy permits.

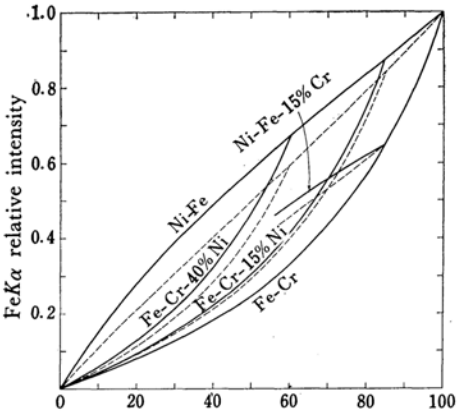

Fig. 2(b). Theoretical intensity of Fe*K*α fluorescent X-rays, solid curves show the sum of the primary and the secondary, and broken curves show the primary fluorescent X-ray intensity only. Conditions are equal to Fig. 1.

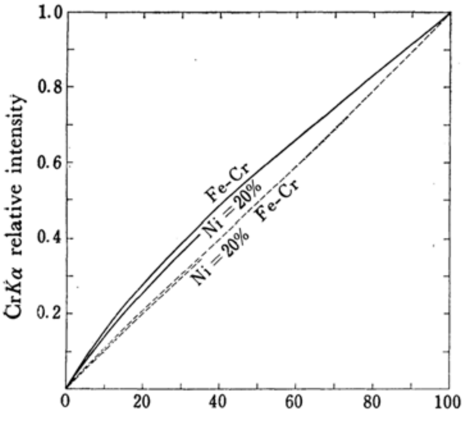

Fig. 3. Theoretical intensity of Cr*K*α fluorescent X-rays from Fe-Cr binary alloys and Fe-Cr-20% Ni ternary alloys. Solid curves show the total fluorescent X-ray intensity and broken curves show the primary only.

Experimental

In order to verify the calculated results, experiments were made on the nickel-iron-chromium alloys whose compositions are shown in Table 4. The experimental conditions are given in Table 5. The observed results are shown as filled circles in Figs. 4, 5, and 6 for Ni*K*α Fe*K*α, and Cr*K*α respectively. In Fig. 5, open circles give the calculated intensities of Fe*K*α corresponding to the experimental intensities (shown by filled circles).

Table 4. Compositions of the samples (wt%)

Ni	Cr	Fe*	C	Si	Mn	Cu
22.84	23.60	51.97	0.07	0.57	0.78	0.07
22.50	18.28	57.18	0.05	0.38	1.59	0.01
22.02	18.15	57.89	0.02	0.40	1.49	0.01
22.02	18.00	58.01	0.06	0.42	1.46	0.01
21.97	17.85	58.15	0.11	0.43	1.46	0.01
20.66	14.90	63.09	0.07	0.44	0.73	0.08
20.00	29.00	49.43	0.07	0.52	0.89	0.07
19.08	23.90	55.55	0.07	0.52	0.78	0.07
19.05	18.80	60.76	0.08	0.40	0.80	0.08
16.09	15.20	67.38	0.07	0.41	0.74	0.08
14.98	24.80	58.75	0.07	0.52	0.78	0.07
14.96	10.10	73.30	0.08	0.63	0.88	0.10
14.88	19.70	63.98	0.08	0.43	0.82	0.08
13.27	17.95	67.06	0.06	0.49	1.06	0.08
13.25	19.15	65.89	0·07	0.53	1.01	0.07
13.23	16.45	67.59	0.06	0.49	1.10	0.08
12.90	17.65	67.45	0.07	0.61	1.21	0.08
11.67	15.50	71.47	0.07	0.46	0.74	0.08
11.20	17.75	69.09	0.07	0.56	1.21	0.09
10.31	24.80	58.74	0.07	0.57	0.74	0.07
10.03	10.30	78.04	0.07	0.63	0.89	0.11
9.89	19.50	69.19	0.08	0.38	0.84	0.09
9.37	18.00	70.78	0.09	0.56	1.20	0.09
5.36	15.15	77.82	0.08	0.63	0.91	0.12
5.32	3.30	90.05	0.11	0.39	0.50	0.29
5.13	20.10	73.25	0.08	0.42	0.90	0.09
4.97	10.30	83.00	0.07	0.68	0.94	0.12
2.28	1.30	95.11	0.13	0.35	0.51	0.28
2.17	3.30	93.21	0.10	0.37	0.50	0.31
1.15	1.20	96.32	0.13	0.35	0.53	0.28
1.10	3.10	94.41	0.11	0.40	0.55	0.30
2.12	—	96.83	0.05	0.34	0.50	0.16
7.51	—	91.40	0.05	0.34	0.54	0.16
14.76	—	84.37	0.04	0.25	0.43	0.15
23.56	—	75.54	0.04	0.26	0.47	0.13
30.94	—	68.65	0.03	0.11	0.18	0.09
44.10	—	55.50	0.05	0.07	0.19	0.09
—	3.60	95.15	0.15	0.41	0.57	0.12
—	5.60	93.15	0.15	0.39	0.59	0.12
—	7.60	91.09	0.15	0.42	0.63	0.11
—	9.10	89.62	0.15	0.47	0.55	0.11
—	13.10	85.53	0.15	0.47	0.65	0.10
—	14.95	83.70	0.15	0.52	0.58	0.10
—	17.60	81.04	0.15	0.51	0.62	0.08
—	23.50	75.01	0.15	0.53	0.71	0.10

* Iron percentages are given by the balance.

Conclusion

The theoretical intensities of the primary, the secondary, and the tertiary fluorescent X-rays from nickel-iron-chromium ternary systems at every fifth percentage point of each element from 0 to 100 percent were calculated by using an electronic computor; these results were confirmed by the experiments.

Agreements between the theoretical and the experimental results are good, with errors of less than 1 percent. It is thought that these errors are mainly caused by such minor constituents as

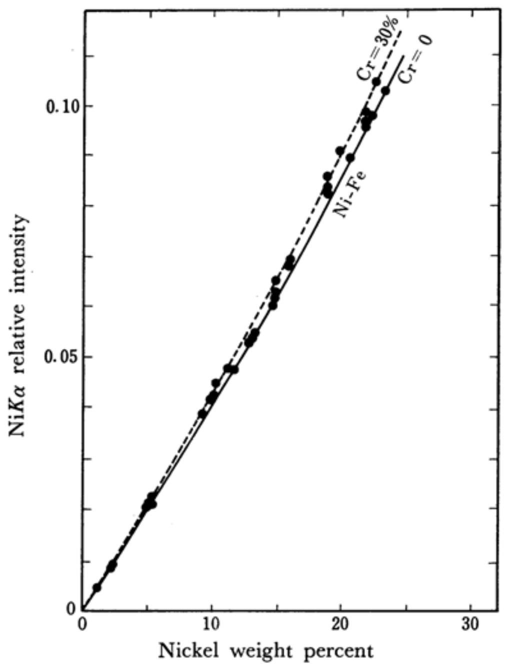

Fig. 4. Experimental results for Ni$K\alpha$ fluorescent X-ray intensity. Curves show the theoretical and filled circles are experimental.

TABLE 5. EXPERIMENTAL CONDITIONS AND APPARATUS

1	Apparatus	Shimadzu FX-403
2	Analysing crystal	LiF (in air)
3	Collimation (Sollar-slit)	1st 25′ 2nd 2°20′
4	Detector	G-M counter (Amperex) dead time 130 μ sec.
5	X-ray tube	Machlett OEG-50S (W target)
6	Irradiated area of the sample	7 mm dia.
7	Angle made by surface of sample with incident and emitted X-rays	60° and 30°
8	Condition of measurement	
	Tube voltage	30 K. V. P. full-wave rectified
	Tube current	5 mA
9	X-ray intensity measurement	Fixed time operation (measurement of the time interval required to 4×10^4 counts.)

Mn, Si, Mo, and Ti. A discussion of the correction method for these minor constituents will be published in the near future.

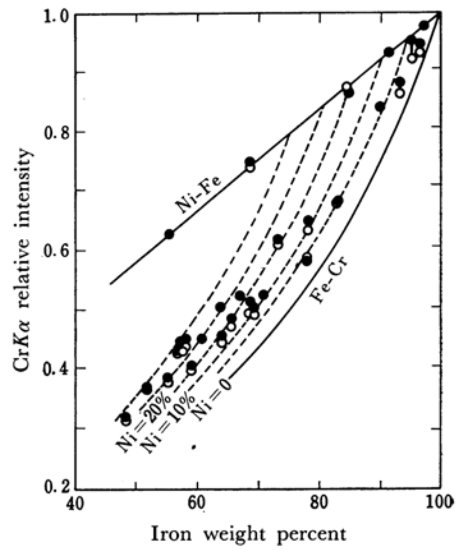

Fig. 5. Experimental results for Fe$K\alpha$ fluorescent X-ray intensity.
—— Theoretical intensity of Ni-Fe-Cr ternary system.
● Experimental value.
○ Calculated value correspond to experiment.

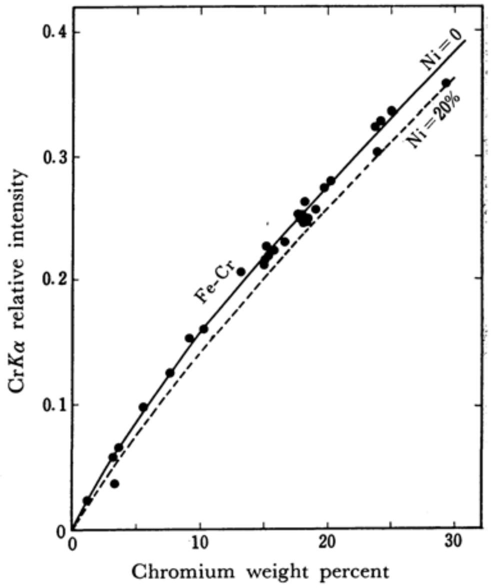

Fig. 6. Experimental results for Cr$K\alpha$ fluorescent X-ray intensity.
—— Theoretical intensity of Fe-Cr binary system.
---- Theoretical intensity of Fe-Cr-20%Ni ternary system.
● Experimental value.

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