4. Fluorescence and Coster-Kronig Yields

Table 3 lists atomic yields for the K and L shells of elements with Z=1-110 from the evaluation of Krause[1]. The yields are for singly ionized atoms, and do not include corrections for solid state, chemical, or multiple ionization effects. These corrections are expected to be small[2] for all except the lighter elements, and small throughout the spectra, except at the onsets and cutoffs of Coster-Kronig transitions.

Fluorescence yields (ω_K, ω_{L_i}, ...) represent the probabilities for the filling of vacancies in the corresponding atomic shells by radiative processes, and are used for calculating x-ray and Auger-electron intensities. The intrashell radiative yields f'_{12} and f'_{13} represent the probabilities for x-ray emission per vacancy in the L_1 subshell, resulting in subsequent vacancies in the L_2 and L_3 subshells, respectively. The intrashell radiative yields are included in ω_{L_i}; however, because $f'_{12} << f'_{13}$, the yield f'_{12} is not listed separately. The Coster-Kronig yields $f_{12,}$ $f_{13,}$ and f_{23} represent the probabilities for electron emission per vacancy in an L subshells, resulting in vacancies in higher L subshell. Finally, Auger yields (a) represent the probabilities for electron emission per vacancy in given atomic shells, resulting in vacancies in higher atomic shells. Auger yields are not given explicitly in Table 3, but can be calculated for any shell i from the equation

$$a_i = 1 - \omega_i + f_i \ ,$$

where $f_1 = f_{12} + f_{13}$ and $f_2 \equiv f_{23}$.

The atomic yields in Table 3 are based on based on both experimental and theoretical information. The ω_k fluorescence yields in Table 3 are updated values from a polynomial fit to selected experimental data by Bambynek.[3] Estimates of their percentage uncertainties, listed for various ranges of atomic numbers, are given in Table 4. These are based on the presumed and stated reliabilities of the input data or calculations, the number or lack of measurements, and the degrees of compatibility of the different relevant data.

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[1] M.O. Krause, *J. Phys. Chem. Ref. Data* **8**, 307 (1979).

[2] S.T. Manson, J.L. Dehmer, and M. Inokuti, *Bull. Am. Phys. Soc.* **22**, 1332 G33 (1977).

[3] W. Bambynek, post-deadline abstract published in the Proceedings of the Conference on X-ray and Inner-Shell Processes in Atoms, Molecules and Solids, Leipzig, August 20-24, 1984.

Table 3. Fluorescence and Coster-Kronig Yields

El	ω_K	ω_{L_1}	ω_{L_2}	ω_{L_3}	f_{12}	f_{13}	f_{13}'	f_{23}
1 H	0.00002							
2 He	0.0001							
3 Li	0.0003							
4 Be	0.0007							
5 B	0.0014							
6 C	0.0026							
7 N	0.0043							
8 O	0.0069							
9 F	0.010							
10 Ne	0.015							
11 Na	0.021							
12 Mg	0.029	0.000029	0.0012	0.0012	0.32	0.64	0.000020	
13 Al	0.039	0.000026	0.00075	0.00075	0.32	0.64	0.000016	
14 Si	0.050	0.000030	0.00037	0.00038	0.32	0.64	0.000014	
15 P	0.064	0.000039	0.00031	0.00031	0.32	0.63	0.000012	
16 S	0.080	0.000074	0.00026	0.00026	0.32	0.62	0.000014	
17 Cl	0.099	0.00012	0.00024	0.00024	0.32	0.62	0.000014	
18 Ar	0.120	0.00018	0.00022	0.00022	0.31	0.62	0.000013	
19 K	0.143	0.00024	0.00027	0.00027	0.31	0.62	0.000012	
20 Ca	0.169	0.00031	0.00033	0.00033	0.31	0.61	0.000014	
21 Sc	0.196	0.00039	0.00084	0.00084	0.31	0.60	0.000014	
22 Ti	0.226	0.00047	0.0015	0.0015	0.31	0.59	0.000015	
23 V	0.256	0.00058	0.0026	0.0026	0.31	0.58	0.000016	
24 Cr	0.288	0.00071	0.0037	0.0037	0.31	0.57	0.000018	
25 Mn	0.321	0.00084	0.0050	0.0050	0.30	0.58	0.000019	
26 Fe	0.355	0.0010	0.0063	0.0063	0.30	0.57	0.000021	
27 Co	0.388	0.0012	0.0077	0.0077	0.30	0.56	0.000023	
28 Ni	0.421	0.0014	0.0086	0.0093	0.30	0.55	0.000024	0.028
29 Cu	0.454	0.0016	0.0100	0.011	0.30	0.54	0.000026	0.028
30 Zn	0.486	0.0018	0.011	0.012	0.29	0.54	0.000028	0.026
31 Ga	0.517	0.0021	0.012	0.013	0.29	0.53	0.000030	0.032
32 Ge	0.546	0.0024	0.013	0.015	0.28	0.53	0.000032	0.050
33 As	0.575	0.0028	0.014	0.016	0.28	0.53	0.000034	0.063
34 Se	0.602	0.0032	0.016	0.018	0.28	0.52	0.000036	0.076
35 Br	0.628	0.0036	0.018	0.020	0.28	0.52	0.000038	0.088
36 Kr	0.652	0.0041	0.020	0.022	0.27	0.52	0.000041	0.100
37 Rb	0.674	0.0046	0.022	0.024	0.27	0.52	0.000044	0.109
38 Sr	0.696	0.0051	0.024	0.026	0.27	0.52	0.000047	0.117
39 Y	0.716	0.0059	0.026	0.028	0.26	0.52	0.000052	0.126
40 Zr	0.734	0.0068	0.028	0.031	0.26	0.52	0.000058	0.132
41 Nb	0.751	0.0094	0.031	0.034	0.10	0.61	0.000078	0.137
42 Mo	0.767	0.0100	0.034	0.037	0.10	0.61	0.000081	0.141
43 Tc	0.782	0.011	0.037	0.040	0.10	0.61	0.000088	0.144
44 Ru	0.796	0.012	0.040	0.043	0.10	0.61	0.000096	0.148
45 Rh	0.807	0.013	0.043	0.046	0.10	0.60	0.000100	0.150
46 Pd	0.820	0.014	0.047	0.049	0.10	0.60	0.00011	0.151
47 Ag	0.831	0.016	0.051	0.052	0.10	0.59	0.00012	0.153
48 Cd	0.842	0.018	0.056	0.056	0.10	0.59	0.00014	0.155
49 In	0.851	0.020	0.061	0.060	0.10	0.59	0.00016	0.157
50 Sn	0.860	0.037	0.065	0.064	0.17	0.27	0.00030	0.157
51 Sb	0.868	0.039	0.069	0.069	0.17	0.28	0.00032	0.156
52 Te	0.875	0.041	0.074	0.074	0.18	0.28	0.00034	0.155
53 I	0.882	0.044	0.079	0.079	0.18	0.28	0.00037	0.154
54 Xe	0.888	0.046	0.083	0.085	0.19	0.28	0.00040	0.154
55 Cs	0.894	0.049	0.090	0.091	0.19	0.28	0.00043	0.154
56 Ba	0.900	0.052	0.096	0.097	0.19	0.28	0.00047	0.153
57 La	0.905	0.055	0.103	0.104	0.19	0.29	0.00051	0.153
58 Ce	0.910	0.058	0.110	0.111	0.19	0.29	0.00055	0.153
59 Pr	0.914	0.061	0.117	0.118	0.19	0.29	0.00060	0.153
60 Nd	0.918	0.064	0.124	0.125	0.19	0.30	0.00066	0.152
61 Pm	0.922	0.066	0.132	0.132	0.19	0.30	0.00072	0.151
62 Sm	0.926	0.071	0.140	0.139	0.19	0.30	0.00079	0.150
63 Eu	0.929	0.075	0.149	0.147	0.19	0.30	0.00087	0.149
64 Gd	0.932	0.079	0.158	0.155	0.19	0.30	0.00096	0.147
65 Tb	0.935	0.083	0.167	0.164	0.19	0.30	0.0011	0.145
66 Dy	0.938	0.089	0.178	0.174	0.19	0.30	0.0012	0.143
67 Ho	0.940	0.094	0.189	0.182	0.19	0.30	0.0013	0.142
68 Er	0.942	0.100	0.200	0.192	0.19	0.30	0.0014	0.140
69 Tm	0.945	0.106	0.211	0.201	0.19	0.29	0.0016	0.139
70 Yb	0.947	0.112	0.222	0.210	0.19	0.29	0.0018	0.138
71 Lu	0.949	0.120	0.234	0.220	0.19	0.28	0.0020	0.136
72 Hf	0.950	0.128	0.246	0.231	0.18	0.28	0.0023	0.135
73 Ta	0.952	0.137	0.258	0.243	0.18	0.28	0.0026	0.134
74 W	0.954	0.147	0.270	0.255	0.17	0.28	0.0028	0.133
75 Re	0.955	0.144	0.283	0.268	0.16	0.33	0.0030	0.130
76 Os	0.957	0.130	0.295	0.281	0.16	0.39	0.0029	0.128
77 Ir	0.958	0.120	0.308	0.294	0.15	0.45	0.0028	0.126
78 Pt	0.959	0.114	0.321	0.306	0.14	0.50	0.0028	0.124
79 Au	0.960	0.107	0.334	0.320	0.14	0.53	0.0028	0.122
80 Hg	0.962	0.107	0.347	0.333	0.13	0.56	0.0030	0.120
81 Tl	0.962	0.107	0.360	0.347	0.13	0.57	0.0032	0.118
82 Pb	0.963	0.112	0.373	0.360	0.12	0.58	0.0035	0.116
83 Bi	0.964	0.117	0.387	0.373	0.11	0.58	0.0038	0.113
84 Po	0.965	0.122	0.401	0.386	0.11	0.58	0.0042	0.111
85 At	0.966	0.128	0.415	0.399	0.10	0.59	0.0047	0.111
86 Rn	0.967	0.134	0.429	0.411	0.10	0.58	0.0052	0.110
87 Fr	0.967	0.139	0.443	0.424	0.10	0.58	0.0058	0.109
88 Ra	0.968	0.146	0.456	0.437	0.09	0.58	0.0064	0.108
89 Ac	0.969	0.153	0.468	0.450	0.09	0.58	0.0071	0.108
90 Th	0.969	0.161	0.479	0.463	0.09	0.57	0.0078	0.108
91 Pa	0.970	0.162	0.472	0.476	0.08	0.58	0.0084	0.139
92 U	0.970	0.176	0.467	0.489	0.08	0.57	0.0097	0.167
93 Np	0.971	0.187	0.466	0.502	0.07	0.57	0.011	0.192
94 Pu	0.971	0.205	0.464	0.514	0.05	0.56	0.013	0.198
95 Am	0.971	0.218	0.471	0.526	0.05	0.55	0.014	0.203
96 Cm	0.972	0.228	0.479	0.539	0.04	0.55	0.016	0.200
97 Bk	0.972	0.236	0.485	0.550	0.04	0.54	0.017	0.198
98 Cf	0.972	0.244	0.490	0.560	0.03	0.54	0.019	0.197
99 Es	0.972	0.253	0.497	0.570	0.03	0.54	0.021	0.196
100 Fm	0.973	0.263	0.506	0.579	0.03	0.53	0.023	0.194
101 Md	0.973	0.272	0.515	0.588	0.02	0.53	0.026	0.191
102 No	0.973	0.280	0.524	0.596	0.02	0.52	0.028	0.189
103 Lr	0.973	0.282	0.533	0.604	0.01	0.53	0.030	0.185
104 Rf	0.973	0.291	0.544	0.611	0.01	0.52	0.033	0.181
105 Ha	0.973	0.300	0.553	0.618	0.01	0.51	0.035	0.178
106 Sg	0.973	0.310	0.562	0.624		0.51	0.038	0.174
107 Ns	0.973	0.320	0.573	0.630		0.50	0.042	0.171
108 Hs	0.973	0.331	0.584	0.635		0.50	0.046	0.165
109 Mt	0.973	0.343	0.590	0.640		0.49	0.050	0.163
110	0.973	0.354	0.598	0.644		0.48	0.054	0.158

Table 4. Estimated Percent Uncertainties for Fluorescence and Coster-Kronig Yields

Z(range)	ω_K	ω_{L_1}	ω_{L_2}	ω_{L_3}	f_{12}	f_{13}	f_{23}
5-10	40-10[a]						
10-20	10-5	>30[a]	>25[a]	>25[a]	10[a]	5[a]	
20-30	5-3	30[a]	25[a,b]	25	15[a]	10[a]	40[a]
30-40	3	30[b]	25	20	15	10	30-20
40-50	2	30-20[b]	25-10	20-10	20[b]	10[b]	20
50-60	2-1	20-15	10	10-5	20	15	20
60-70	1	15	10-5	5	15	10	20-15[a]
70-80	1	15[b]	5	5-3	20[b]	10-5[b]	15
80-90	<1	15	5	3	10	5	15
90-100	<1	15-20	10[b]	3-5	10-50	5-10	15[b]
100-110	1	20	10	5	50-100	15	20

[a] In these regions, yields for molecules and solids may differ from those for atoms by more than the values quoted.

[b] Near breaks in the yield curves, uncertainties may exceed those listed.