

APPENDIX A

Strongest characteristic X-ray line energies (keV)

Data below are taken from *Tables of Physical & Chemical Constants (16th edition 1995). 4.2.1 X-ray absorption edges, characteristic X-ray lines and fluorescence yields. Kaye & Laby Online. Version 1.0 (2005)*

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Atomic number and element	KM _{III}	KM _{II}	KL _{III}	KL _{II}	L _I N _{III}	L _I M _{III}	L _I M _{II}	L _{II} N _{IV}	L _{II} M _{IV}	L _{III} N _V	L _{III} M _V	L _{III} M _{IV}	L _{III} M _I
	K β_1	K β_3	K α_1	K α_2	L γ_3	L β_3	L β_4	L γ_1	L β_1	L β_2	L α_1	L α_2	L $_I$
Intensity	~20	~10	100	50–53	~5	50–35	20	~5	~50	~5	~90	10	20–5
11 Na	1.071		1.041										
12 Mg	1.302		1.253										
13 Al	1.557		1.487	1.486									
14 Si	1.836		1.740	1.739									
15 P	2.139		2.014	2.013									
16 S	2.464		2.308	2.307									
17 Cl	2.816		2.622	2.620									
18 Ar	3.190		2.958	2.956									
19 K	3.590		3.314	3.311									
20 Ca	4.013		3.692	3.688									
21 Sc	4.461		4.090	4.086					0.400			0.395	0.348
22 Ti	4.932		4.511	4.505					0.458			0.452	0.395
23 V	5.427		4.952	4.944		0.585			0.519			0.511	0.446
24 Cr	5.947		5.415	5.405		0.654			0.583			0.573	0.500
25 Mn	6.490		5.899	5.888		0.721			0.649			0.637	0.556
26 Fe	7.058		6.404	6.391		0.792			0.719			0.705	0.615
27 Co	7.649		6.930	6.915		0.870			0.791			0.776	0.678
28 Ni	8.265		7.478	7.461		0.941			0.869			0.852	0.743
29 Cu	8.905	8.903	8.048	8.028		1.023	1.019		0.950			0.930	0.811
30 Zn	9.572	9.567	8.639	8.616		1.107	1.102		1.035			1.012	0.884
31 Ga	10.271	10.261	9.252	9.231		1.197	1.191		1.125			1.098	0.957
32 Ge	10.983	10.978	9.887	9.856		1.294	1.289		1.218			1.188	1.036
33 As	11.727	11.721	10.544	10.509		1.386	1.380		1.316			1.282	1.120
34 Se	12.496	12.489	11.222	11.181		1.492	1.485		1.419			1.379	1.204
35 Br	13.292	13.285	11.924	11.878		1.600	1.593		1.523			1.480	1.294
36 Kr	14.113	14.105	12.650	12.598		1.706	1.698		1.637			1.586	1.386
37 Rb	14.962	14.952	13.396	13.336	2.051 ²	1.827	1.817		1.752		1.694	1.692	1.482
38 Sr	15.836	15.826	14.166	14.098	2.197 ²	1.947	1.937		1.872		1.806	1.804	1.582
39 Y	16.737	16.725	14.958	14.882	2.347 ²	2.072	2.060		1.996		1.923	1.920	1.685
40 Zr	17.662	17.649	15.770	15.692	2.503 ²	2.200	2.187	2.292	2.118	2.215	2.043	2.040	1.792
41 Nb	18.623	18.606	16.615	16.521	2.660 ²	2.336	2.319	2.449	2.257	2.357	2.166	2.163	1.902
42 Mo	19.608	19.590	17.479	17.374	2.825 ²	2.473	2.455	2.611	2.396	2.508	2.295	2.291	2.016
43 Tc	20.619	20.599	18.367	18.251	3.001 ²	2.618	2.598	2.778	2.537	2.664	2.424	2.421	2.131
44 Ru	21.656	21.637	19.279	19.150	3.179 ²	2.763	2.744	2.952	2.683	2.825	2.556	2.554	2.253
45 Rh	22.723	22.698	20.216	20.073	3.365 ²	2.915	2.890	3.132	2.835	2.992	2.698	2.692	2.377
46 Pd	23.819	23.792	21.178	21.021	3.557	3.073	3.046	3.318	2.990	3.163	2.838	2.833	2.503
47 Ag	24.943	24.912	22.163	21.991	3.754	3.234	3.203	3.511	3.151	3.342	2.985	2.979	2.634

	$K\beta_1$	$K\beta_3$	$K\alpha_1$	$K\alpha_2$	$L\gamma_3$	$L\beta_3$	$L\beta_4$	$L\gamma_1$	$L\beta_1$	$L\beta_2$	La_1	La_2	L_1
<i>Intensity</i>	~20	~10	100	53–65	~5	35–20	20	5–25	100	5–20	~90	10	20–5
48 Cd	26.095	26.061	23.173	22.985	3.960	3.402	3.368	3.710	3.319	3.525	3.134	3.131	2.767
49 In	27.275	27.237	24.209	24.002	4.169	3.572	3.534	3.915	3.487	3.712	3.288	3.280	2.905
50 Sn	28.491	28.439	25.272	25.044	4.377	3.750	3.703	4.127	3.661	3.903	3.442	3.433	3.045
51 Sb	29.725	29.677	26.359	26.110	4.609	3.932	3.884	4.345	3.843	4.101	3.604	3.594	3.189
52 Te	30.995	30.944	27.472	27.201	4.837	4.120	4.069	4.568	4.030	4.302	3.770	3.759	3.336
53 I	32.295	32.239	28.612	28.317	5.072	4.313	4.257	4.799	4.221	4.509	3.938	3.926	3.485
54 Xe	33.625	33.562	29.779	29.459	5.319	4.516	4.453	5.035	4.415	4.720	4.110	4.095	3.625
55 Cs	34.985	34.918	30.973	30.625	5.567	4.719	4.652	5.278	4.619	4.936	4.289	4.271	3.795
56 Ba	36.378	36.303	32.194	31.817	5.820	4.928	4.853	5.529	4.827	5.158	4.470	4.450	3.954
57 La	37.802	37.721	33.442	33.034	6.080	5.143	5.062	5.786	5.037	5.385	4.651	4.629	4.122
58 Ce	39.258	39.170	34.720	34.279	6.349	5.364	5.276	6.051	5.261	5.617	4.839	4.820	4.289
59 Pr	40.748	40.653	36.026	35.550	6.622	5.592	5.497	6.321	5.485	5.853	5.034	5.009	4.455
60 Nd	42.272	42.166	37.361	36.847	6.902	5.829	5.723	6.597	5.722	6.091	5.231	5.208	4.633
61 Pm	43.825	43.713	38.725	38.171	7.193	6.071	5.959	6.880	5.962	6.334	5.433	5.408	4.785
62 Sm	45.413	45.289	40.118	39.523	7.490	6.319	6.195	7.169	6.205	6.582	5.635	5.610	4.995
63 Eu	47.036	46.902	41.542	40.902	7.794	6.574	6.440	7.467	6.455	6.835	5.843	5.815	5.177
64 Gd	48.696	48.554	42.996	42.309	8.100	6.832	6.690	7.772	6.713	7.034	6.058	6.026	5.362
65 Tb	50.382	50.228	44.481	43.744	8.423	7.096	6.942	8.086	6.976	7.358	6.273	6.239	5.547
66 Dy	52.119	51.956	45.999	45.208	8.743	7.371	7.208	8.409	7.249	7.627	6.496	6.458	5.743
67 Ho	53.878	53.707	47.547	46.699	9.080	7.650	7.479	8.740	7.529	7.901	6.719	6.681	5.944
68 Er	55.681	55.491	49.128	48.221	9.425	7.942	7.752	9.078	7.813	8.180	6.951	6.906	6.153
69 Tm	57.513	57.303	50.742	49.773	9.782	8.236	8.026	9.426	8.103	8.465	7.181	7.134	6.342
70 Yb	59.374	59.157	52.389	51.354	10.148	8.531	8.314	9.781	8.402	8.755	7.415	7.367	6.546
71 Lu	61.286	61.049	54.070	52.965	10.518	8.844	8.607	10.144	8.709	9.049	7.655	7.604	6.753
72 Hf	63.236	62.979	55.790	54.611	10.890	9.153	8.896	10.517	9.016	9.348	7.891	7.837	6.960
73 Ta	65.221	64.946	57.533	56.277	11.278	9.488	9.213	10.894	9.345	9.649	8.147	8.089	7.173
74 W	67.244	66.951	59.318	57.982	11.675	9.819	9.526	11.284	9.671	9.959	8.396	8.335	7.388
75 Re	69.309	68.994	61.140	59.718	12.082	10.161	9.846	11.682	10.006	10.273	8.651	8.584	7.604
76 Os	71.416	71.077	63.001	61.487	12.503	10.515	10.176	12.092	10.349	10.592	8.905	8.835	7.822
77 Ir	73.560	73.203	64.896	63.287	12.925	10.865	10.508	12.514	10.705	10.919	9.175	9.096	8.046
78 Pt	75.751	75.364	66.832	65.123	13.363	11.231	10.844	12.944	11.073	11.251	9.439	9.364	8.271
79 Au	77.985	77.580	68.804	66.990	13.806	11.609	11.204	13.383	11.432	11.585	9.705	9.618	8.494
80 Hg	80.261	79.822	70.819	68.894	14.258	11.987	11.548	13.834	11.823	11.927	9.999	9.898	8.722
81 Tl	82.575	82.384	72.872	70.832	14.736	13.387	12.196	14.293	12.217	12.272	10.271	10.117	8.953
82 Pb	84.936	84.450	74.969	72.804	15.222	12.791	12.305	14.769	12.618	12.625	10.555	10.453	9.185
83 Bi	87.354	86.831	77.118	74.815	15.717	13.205	12.682	15.261	13.031	12.981	10.836	10.728	9.421
84 Po	89.801	89.250	79.301	76.863	16.230	13.628	13.077	15.756	13.452	13.342	11.131	11.014	9.664
85 At	92.302	91.722	81.523	78.943	16.748	14.067	13.487	16.262	13.882	13.708	11.427	11.302	9.858
86 Rn	94.866	94.246	83.793	81.065	17.262	14.511	13.891	16.777	14.323	14.079	11.727	11.595	10.085
87 Fr	97.477	96.807	86.114	83.231	17.805	14.976	14.306	17.307	14.775	14.456	12.031	11.892	10.340
88 Ra	100.130	99.432	88.476	85.434	18.352	15.443	14.745	17.848	15.238	14.839	12.340	12.196	10.622
89 Ac	102.846	102.101	90.884	87.675	18.922	15.931	15.186	18.402	15.711	15.227	12.652	12.502	10.835
90 Th	105.611	104.831	93.358	89.952	19.498	16.419	15.639	18.993	16.215	15.622	12.970	12.809	11.119
91 Pa	108.435	107.606	95.883	92.287	20.095	16.924	16.095	19.581	16.715	16.022	13.300	13.119	11.366
92 U	111.303	110.424	98.440	94.659	20.712	17.454	16.575	20.167	17.219	16.429	13.614	13.438	11.619
93 Np	114.243	113.312	101.068	97.077	21.340	17.992	17.061	20.785	17.751	16.840	13.944	13.760	11.890
94 Pu	117.261	116.277	103.761	99.552	21.982	18.540	17.556	21.417	18.293	17.256	14.279	14.084	12.124

	$K\beta_1$	$K\beta_3$	$K\alpha_1$	$K\alpha_2$	$L\gamma_3$	$L\beta_3$	$L\beta_4$	$L\gamma_1$	$L\beta_1$	$L\beta_2$	$L\alpha_1$	$L\alpha_2$	L_1
<i>Intensity</i>	~20	~10	100	53–65	~5	35–20	20	5–25	100	5–20	~90	10	20–5
95 Am	120.360	119.317	106.523	102.083	22.637	19.106	18.063	22.065	18.852	17.676	14.617	14.412	12.384
96 Cm	123.423	122.325	109.290	104.441	23.306	19.663	18.565		19.552		14.959	14.703	
97 Bk	126.663	125.443	112.138	107.205	24.040	20.348	19.128		20.019		15.320	15.086	
98 Cf	130.851	129.601	116.030	110.710	24.831	21.001	19.751		20.763		15.677	15.443	
99 Es	134.238	132.916	119.080	113.470	25.579	21.648	20.326		21.390		16.036	15.780	
100 Fm	137.693	136.347	122.190	116.280	26.334	22.303	20.957		22.044		16.402	16.134	
101Md	141.234	139.761	125.390	119.170	27.120	22.984	21.511		22.707		16.768	16.487	
102 No	144.852	143.295	128.660	122.100	27.932	23.692	22.135		23.403		17.139	16.843	
103 Lw	148.670	146.920	132.020	125.100	28.760	24.530	22.780		24.130		17.500	17.210	

Approximate K and L line intensities are given at the head of the columns in the table, relative to the line in the series which is normally the strongest. The values given are based on the compilation of experimental relative intensities of Salem, Panossian and Krause and the intensities calculated by Scofield (Salem *et al.*, pp. 121–37).

Unresolved lines:

1— $KN_{II,III}$ ($K\beta_2$); 2— $L_1N_{II,III}$ ($L\gamma_{2,3}$)

Depending on the resolving power of the dispersing system used (e.g. crystal spectrometer, solid state energy dispersive detector) line pairs shown separately in the table may not be resolved and the effective energy of the doublet will be close to the mean value weighted by the relative intensity of the components.

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