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INTERNATIONAL TABLES
FOR
X-RAY CRYSTALLOGRAPHY



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INTERNATIONAL TABLES

FOR

X-RAY CRYSTALLOGRAPHY

VOL. I. SYMMETRY GROUPS

VOL. II. MATHEMATICAL TABLES

VOL. III. PHYSICAL AND CHEMICAL TABLES

VOL. IV. REVISED AND SUPPLEMENTARY TABLES



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FOR
X-RAY CRYSTALLOGRAPHY

Volume IV

REVISED AND SUPPLEMENTARY TABLES
TO VOLUMES II AND III

Editors

JAMES A. IBERS and WALTER C. HAMILTON*



*Deceased 23 January, 1973.

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Introduction

JAMES A. IBERS and WALTER C. HAMILTON

Purpose and Scope of the Tables

During the roughly ten years which have passed since the publication in 1962 of Volume III of *International Tables for X-ray Crystallography*, greatly increased experimental and theoretical activity in all areas of crystallography has occurred. In particular, many of the physical and chemical data appearing in Volume III have been superseded. The principal motivation for the present Volume IV is to provide revised values for atomic scattering factors, X-ray wavelengths, and atomic absorption coefficients. At the same time a number of special topics, mainly mathematical in content, which were not included in Volume II, have developed to the extent that their inclusion seems worthwhile.

We thus include here revised as well as new material. Because much of this information supersedes corresponding material in the earlier volumes, the present volume should always be consulted first. The index to the present volume is a cumulative index for all four volumes. When specific information included in Volume IV supersedes material in an earlier volume, the reference to the earlier volume is included parenthetically. In such cases, the numerical values of Volume IV should be used, but the user should consult the earlier volumes for the sometimes extensive textual material accompanying the tables.

The Editors alone take responsibility for the choice of new material included in this volume. Such new

material includes diffractometer calculations, analysis of thermal motion in crystals, and some aspects of direct methods for phase determination. Although some of this material is more textual than tabular, it is of such great importance to most structural crystallographers, and its development has been so rapid since the appearance of the earlier volumes, that we decided to include it here. Omission of other topics should not be interpreted as an indication of their relative unimportance. Some choices had to be made that reflect both the biases of the Editors and the desire not to delay publication.

Acknowledgments

The Editors wish to express their indebtedness to all the authors, not only for their contributions but for their patience during the long editorial process. We also thank the authors' institutions for providing time and facilities for the preparation of this important material for the international scientific community. In particular, we thank the United States Atomic Energy Commission for partial support in the preparation of Sections 1, 2, 3, 4, and 5; the Naval Research Laboratory for support of Section 6; the National Bureau of Standards Office of Standard Reference Data for partial support of Sections 1 and 2.1; the Defense Atomic Support Agency for partial support of Section 2.1, and the National Science Foundation for partial support of Section 1 and Section 2.5.

Section 1

X-RAY WAVELENGTHS

J. A. BEARDEN

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1.1. COMMENTS ON THE TABLES (JAMES A. IBERS AND WALTER C. HAMILTON)	5

1.1. Comments on the Tables

The X-ray emission wavelengths and absorption edges presented in Tables 1.1A and 1.1B are reproduced directly from the work of Bearden [1]. The values are given in terms of a unit of length ($\text{\AA}^*$) defined such that the peak of the W $K\alpha_1$ line is at $0.2090100 \text{ \AA}^*$. There is an uncertainty in the conversion factor of this value to ångströms (10^{-10} m) which is equivalent to the uncertainty in the absolute determination of the wavelength of Cu $K\alpha_1$, hence to the uncertainty in λ , the conversion constant from X-units to ångströms. Bearden adopted a value for λ of $1.002056 \pm 0.000005 \text{ m\AA/X-unit}$, and hence suggested that the values in Tables 1.1A and 1.1B are in $\text{\AA}$ to 5 parts per million (ppm), i.e. $1 \text{ \AA}^* = 1.000000 \pm 0.000005 \text{ \AA}$. The experimental value of λ depends upon the value of N , Avogadro's number, and there is reason to believe [2] that the value of N used by Bearden is in error by more than 5 but probably less than 20 ppm. If the value for λ is revised, the wavelength values in Table 1.1A and 1.1B must be multiplied by $(\lambda/1.002056)$ to obtain

wavelengths in $\text{\AA}$. Since any such change will probably be less than 20 ppm, the wavelengths given here may be considered to be in $\text{\AA}$ by all but those who require the most precise wavelength standards. The probable errors given in the Tables are Bearden's estimates of the error in the ratio of a given wavelength to that of W $K\alpha_1$, taken as the standard. Such a ratio is, of course, independent of any change in the value of λ . The keV values in the Tables are calculated from the $\text{\AA}^*$ values by the relationship:

$$\text{keV} = \frac{12.39810}{\text{\AA}^*}$$

For further information refer to [1].

Because of the likelihood that the wavelength values in ångströms will change slightly in the future, the practice of stating the wavelength value assumed in the determination of precision lattice constants should be continued.

References

- [1] BEARDEN, J. A. *Rev. Mod. Phys.* **39**, 78 (1967). We are indebted to the American Institute of Physics for their permission to reproduce this material.
- [2] DuMOND, J. W. M. Private correspondence (1968); see also DuMOND, J. W. M. *Physics Today*, p. 26 (October, 1965).

I. X-RAY WAVELENGTHS

TABLE 1.1A

X-ray Wavelengths in Å* Units and in keV Arranged by Atomic Number. The Probable Error (p.e.) is the Error in the Last Digit of the Wavelength. Designation Indicates both Conventional Siegbahn Notation, if Applicable, and Transition, e.g. $\beta_1 L_{II} M_{IV}$ Denotes a Transition Between the L_{II} and M_{IV} Levels, which is the $L\beta_1$ Line in Siegbahn Notation

Designation	Å*	p.e.	keV	Designation	Å*	p.e.	keV
3 Lithium				4 Beryllium			
αKL	223.	1	0.0543		114.	1	0.1085
5 Boron				6 Carbon			
αKL	67.6	3	0.1833		44.7	3	0.277
7 Nitrogen				8 Oxygen			
αKL	31.6	4	0.3924		23.62	3	0.5249
9 Fluorine				10 Neon			
$\alpha_{1,2} KL_{II,III}$	18.32	2	0.6768		14.610	3	0.8486
βKM					14.452	5	0.8579
11 Sodium				12 Magnesium			
$\alpha_{1,2} KL_{II,III}$	11.9101	9	1.0410		9.8900	2	1.25360
βKM	11.575	2	1.0711		9.521	2	1.3022
$L_{II,III}M$	407.1	5	0.03045		251.5	5	0.0493
$L_IL_{II,III}$	376	1	0.0330		317	1	0.0392
13 Aluminum				14 Silicon			
$\alpha_2 KL_{II}$	8.34173	9	1.48627		7.12791	9	1.73938
$\alpha_1 KL_{III}$	8.33934	9	1.48670		7.12542	9	1.73998
βKM	7.960	2	1.5574		6.753	1	1.8359
$L_{II,III}$	171.4	5	0.0724		135.5	4	0.0915
$L_IL_{II,III}$	290.	1	0.0428				
15 Phosphorus				16 Sulfur			
$\alpha_2 KL_{II}$	6.160 [†]	1	2.0127		5.37496	8	2.30664
$\alpha_1 KL_{III}$	6.157 [†]	1	2.0137		5.37216	7	2.30784
βKM	5.796	2	2.1390				
$\beta_1 KM$					5.0316	2	2.4640
$\beta_2 KM$					5.0233	3	2.4681
$L_{II,III}M$	103.8	4	0.1194		83.4	3	0.1487
$l, \eta L_{II,III}M_I$							
17 Chlorine				18 Argon			
$\alpha_2 KL_{II}$	4.7307	1	2.62078		4.19474	5	2.95563
$\alpha_1 KL_{III}$	4.7278	1	2.62239		4.19180	5	2.95770
βKM	4.4034	3	2.8156				
$\beta_{1,2} KM_{II,III}$					3.8860	2	3.1905
$\eta L_{II}M_I$	67.33	9	0.1841		55.9 [†]	1	0.2217
$l L_{III}M_I$	67.90	9	0.1826		56.3 [†]	1	0.2201
19 Potassium				20 Calcium			
$\alpha_2 KL_{II}$	3.7445	2	3.3111		3.36166	3	3.68809
$\alpha_1 KL_{III}$	3.7414	2	3.3138		3.35839	3	3.69168
$\beta_{1,2} KM_{II,III}$	3.4539	2	3.5896		3.0897	2	4.0127
$\beta_3 KM_{IV,V}$	3.4413	4	3.6027		3.0746	3	4.0325
21 Scandium				22 Titanium			
$\alpha_2 KL_{II}$	3.0342	1	4.0861		2.75216	2	4.50486
$\alpha_1 KL_{III}$	3.0309 [†]	1	4.0906		2.74851	2	4.51084
$\beta_{1,2} KM_{II,III}$	2.7796	2	4.4605		2.51391	2	4.93181
$\beta_3 KM_{IV,V}$	2.7634	3	4.4865		2.4985	2	4.9623
$\eta L_{II}M_I$	35.13	2	0.3529		30.89	3	0.4013
$\beta_1 L_{II}M_{IV}$	31.02	2	0.3996		27.05	2	0.4584
$l L_{III}M_I$	35.59	3	0.3483		31.36	2	0.3953
$\alpha_{1,2} L_{III}M_{IV,V}$	31.35	3	0.3954		27.42	2	0.4522
23 Vanadium				24 Chromium			
$\alpha_2 KL_{II}$	2.50738	2	4.94464		2.293606	3	5.40551
$\alpha_1 KL_{III}$	2.50356	2	4.95220		2.28970	2	5.41472
$\beta_{1,2} KM_{II,III}$	2.28440	2	5.42729		2.08487	2	5.94671
$\beta_3 KM_{IV,V}$	2.26951	6	5.4629		2.07087	6	5.9869
$\beta_{3,4} L_{II}M_{II,III}$	21.19 [†]	9	0.585		18.96	2	0.654
$\eta L_{II}M_I$	27.34	3	0.4535		24.30	3	0.5102
$\beta_1 L_{II}M_{IV}$	23.88	4	0.5192		21.27	1	0.5828
$l L_{III}M_I$	27.77	1	0.4465		24.78	1	0.5003
$\alpha_{1,2} L_{III}M_{IV,V}$	24.25	3	0.5113		21.64	3	0.5728
$M_{II,III}M_{IV,V}$	337.	9	0.037		309.	9	0.040
25 Manganese				26 Iron			
$\alpha_2 KL_{II}$	2.10578	2	5.88765		1.939980	9	6.39084
$\alpha_1 KL_{III}$	2.101820	9	5.89875		1.936042	9	6.40384
$\beta_{1,2} KM_{II,III}$	1.91021	2	6.49045		1.75661	2	7.05798
$\beta_3 KM_{IV,V}$	1.8971	1	6.5352		1.7442	1	7.1081
$\beta_{3,4} L_{II}M_{II,III}$	17.19	2	0.721		15.65	2	0.792
$\eta L_{II}M_I$	21.85	2	0.5675		19.75	4	0.628
$\beta_1 L_{II}M_{IV}$	19.11	2	0.6488		17.26	1	0.7185
$l L_{III}M_I$	22.29	1	0.5563		20.15	1	0.6152
$\alpha_{1,2} L_{III}M_{IV,V}$	19.45	1	0.6374		17.59	2	0.7050
$M_{II,III}M_{IV,V}$	273.	6	0.045		243.	5	0.051
27 Cobalt				28 Nickel			
$\alpha_2 KL_{II}$	1.792850	9	6.91530		1.661747	8	7.46089
$\alpha_1 KL_{III}$	1.788965	9	6.93032		1.657910	8	7.47815
$\beta_{1,2} KM_{II,III}$	1.62079	2	7.64943		1.500135	8	8.26466
$\beta_3 KM_{IV,V}$	1.60891	3	7.7059		1.48862	4	8.3286
$\beta_{3,4} L_{II}M_{II,III}$	14.31	3	0.870		13.18	1	0.941
$\eta L_{II}M_I$	17.87	3	0.694		16.27	3	0.762
$\beta_1 L_{II}M_{IV}$	15.666	8	0.7914		14.271	6	0.8688
$l L_{III}M_I$	18.292	8	0.6778		16.693	9	0.7427
$\alpha_{1,2} L_{III}M_{IV,V}$	15.972	6	0.7762		14.561	3	0.8515
$M_{II,III}M_{IV,V}$	214.	6	0.058		190.	2	0.0651

TABLE 1.1A (continued)

X-ray Wavelengths in Å* Units and in keV. The Probable Error (p.e.) is the Error in the Last Digit of the Wavelength

Designation	Å*	p.e.	keV	Designation	Å*	p.e.	keV	Designation	Å*	p.e.	keV	Designation	Å*	p.e.	keV
29 Copper				30 Zinc				35 Bromine (Cont.)				36 Krypton (Cont.)			
$\alpha_2 KL_{II}$	1.544390	2	8.02783	$\alpha_2 KL_{II}$	1.439000	8	8.61578	$\beta_{3,4} L_{II}M_{II,III}$	7.767†	9	1.596				
$\alpha_1 KL_{III}$	1.540562	2	8.04778	$\alpha_1 KL_{III}$	1.435155	7	8.63886	$\eta L_{II}M_I$	9.255	1	1.3396				
$\beta_3 KM_{II}$	1.3926	1	8.9029					$\beta_1 L_{II}M_{IV}$	8.1251	5	1.52590	γ_5	7.576†	3	1.6366
$\beta_{1,3} KM_{II,III}$	1.392218	9	8.90529	$\beta_{1,3} KM_{II,III}$	1.29525	2	9.5720	γ_6					7.279	5	1.703
$\beta_2 KN_{II,III}$				$\beta_2 KN_{II,III}$	1.28372	2	9.6580	β_2							
$\beta_5 KM_{IV,V}$	1.38109	3	8.9770	$\beta_5 KM_{IV,V}$	1.2848	1	9.6501	$\beta_2 L_{III}M_I$	9.585	1	1.2935	$\alpha_{1,2} L_{III}M_{IV,V}$	8.3746	5	1.48043
$\beta_{3,4} L_{II}M_{II,III}$	12.122	8	1.0228	$\beta_{3,4} L_{II}M_{II,III}$	11.200	7	1.1070	β_2							
$\eta L_{II}M_I$	14.90	2	0.832	$\eta L_{II}M_I$	13.68	2	0.906	$L_{II}N_{III}$							
$\beta_1 L_{II}M_{IV}$	13.053	3	0.9498	$\beta_1 L_{II}M_{IV}$	11.983	3	1.0347	$M_I M_{II}$	184.6	3	0.0672				
$\beta_1 L_{III}M_I$	15.286	9	0.8111	$\beta_1 L_{III}M_I$	14.02	2	0.884	$M_I M_{III}$	164.7	3	0.0753				
$\alpha_{1,2} L_{III}M_{IV,V}$	13.336	3	0.9297	$\alpha_{1,2} L_{III}M_{IV,V}$	12.254	3	1.0117	$M_{II}M_{IV}$	109.4	3	0.1133				
$M_{II,III}M_{IV,V} 173.$	3	0.072		$M_{II,III}M_{IV,V} 173.$	157.	3	0.079	$M_{II}N_I$	76.9	2	0.1613				
31 Gallium				32 Germanium				$M_{III}M_{IV,V}$	113.8	3	0.1089				
									79.8	3	0.1554				
$\alpha_2 KL_{II}$	1.34399	1	9.22482	$\alpha_2 KL_{II}$	1.258011	9	9.85532	$\zeta_2 M_{IV}N_{II}$	191.1	2	0.06488				
$\alpha_1 KL_{III}$	1.340083	9	9.25174	$\alpha_1 KL_{III}$	1.254054	9	9.88642	$M_{IV}N_{III}$	189.5	3	0.0654				
$\beta_3 KM_{II}$	1.20835	5	10.2603	$\beta_3 KM_{II}$	1.12936	9	10.9780	$\zeta_1 M_{V}N_{III}$	192.6	2	0.06437				
$\beta_1 KM_{III}$	1.20789	2	10.2642	$\beta_1 KM_{III}$	1.12894	2	10.9821								
$\beta_2 KN_{II,III}$	1.19600	2	10.3663	$\beta_2 KN_{II,III}$	1.11686	2	11.1008	37 Rubidium				38 Strontium			
$\beta_5 KM_{IV,V}$	1.1981	2	10.348	$\beta_5 KM_{IV,V}$	1.1195	1	11.0745	$\alpha_2 KL_{II}$	0.92969	1	13.3358		0.87943	1	14.0979
$\beta_4 L_{II}M_{II}$				$\beta_4 L_{II}M_{II}$	9.640	2	1.2861	$\alpha_1 KL_{III}$	0.925553	9	13.3953		0.87526	1	14.1650
$\beta_3 L_{II}M_{III}$				$\beta_3 L_{II}M_{III}$	9.581	2	1.2941	$\beta_3 KM_{II}$	0.82921	3	14.9517		0.78345	3	15.8249
$\beta_{3,4} L_{II}M_{II,III}$	10.359†	8	1.197	$\beta_{3,4} L_{II}M_{II,III}$				$\beta_3 KM_{III}$	0.82868	2	14.9613		0.78292	2	15.8357
$\eta L_{II}M_I$	12.597	2	0.9842	$\eta L_{II}M_I$	11.609	2	1.0680	$\beta_2 KN_{II,III}$	0.81645	3	15.1854		0.77081	3	16.0846
$\beta_1 L_{II}M_{IV}$	11.023	2	1.1248	$\beta_1 L_{II}M_{IV}$	10.175	1	1.2185	$\beta_5 KM_{IV,V}$	0.8219	1	15.085		0.7764	1	15.969
$\beta_1 L_{III}M_I$	12.953	2	0.9572	$\beta_1 L_{III}M_I$	11.965	4	1.0362	$\beta_4 KN_{IV,V}$	0.8154	2	15.205		0.76989	5	16.104
$\alpha_{1,2} L_{III}M_{IV,V}$	11.292	1	1.09792	$\alpha_{1,2} L_{III}M_{IV,V}$	10.4361	8	1.18800	$\beta_4 L_{II}M_{II}$	6.8207	3	1.81771		6.4026	3	1.93643
33 Arsenic				34 Selenium				$\beta_3 L_{II}M_{III}$	6.7876	3	1.82659		6.3672	3	1.94719
$\alpha_2 KL_{II}$	1.17987	1	10.50799	$\alpha_2 KL_{II}$	1.10882	2	11.1814	$\gamma_{2,3} L_{II}N_{II,III}$	6.0458	3	2.0507		5.6445	3	2.1965
$\alpha_1 KL_{III}$	1.17588	1	10.54372	$\alpha_1 KL_{III}$	1.10477	2	11.2224	$\eta L_{II}M_I$	8.0415	4	1.54177		7.5171	3	1.64933
$\beta_3 KM_{II}$	1.05783	5	11.7203	$\beta_3 KM_{II}$	0.99268	5	12.4896	$\beta_1 L_{II}M_{IV}$	7.0759	3	1.75217		6.6239	3	1.87172
$\beta_1 KM_{III}$	1.05730	2	11.7262	$\beta_1 KM_{III}$	0.99218	3	12.4959	$\gamma_5 L_{II}N_{IV}$	6.7553	3	1.83532		6.2961	3	1.96916
$\beta_2 KN_{II,III}$	1.04500	3	11.8642	$\beta_2 KN_{II,III}$	0.97992	5	12.6522	$\beta_1 L_{III}M_I$	8.3636	4	1.48238		7.8362	3	1.58215
$\beta_5 KM_{IV,V}$	1.0488	1	11.822	$\beta_5 KM_{IV,V}$	0.9843	1	12.595	$\alpha_2 L_{III}M_{IV}$	7.3251	3	1.69256		6.8697	3	1.80474
$\beta_{3,4} L_{II}M_{II,III}$	8.929	1	1.3884	$\beta_{3,4} L_{II}M_{II,III}$	8.321†	9	1.490	$\alpha_1 L_{III}M_V$	7.3183	2	1.69413		6.8628	2	1.80656
$\eta L_{II}M_I$	10.734	1	1.1550	$\eta L_{II}M_I$	9.962	1	1.2446	$\beta_4 L_{II}N_I$	6.9842	3	1.77517		6.5191	3	1.90181
$\beta_1 L_{II}M_{IV}$	9.4141	8	1.3170	$\beta_1 L_{II}M_{IV}$	8.7358	5	1.41923	$M_I M_{III}$	144.4	3	0.0859				
$\beta_1 L_{III}M_I$	11.072	1	1.1198	$\beta_1 L_{III}M_I$	10.294	1	1.2044	$M_{II}M_{IV}$	91.5	2	0.1355		85.7	2	0.1447
$\alpha_{1,2} L_{III}M_{IV,V}$	9.6709	8	1.2820	$\alpha_{1,2} L_{III}M_{IV,V}$	8.9900	5	1.37910	$M_{II}N_I$	57.0	2	0.2174		51.3	1	0.2416
$M_V N_{III}$				$M_V N_{III}$	230.	2	0.0538	$M_{III}M_{IV,V}$	96.7	2	0.1282		91.4	2	0.1357
35 Bromine				36 Krypton				$M_{III}N_I$	59.5	2	0.2083		53.6	1	0.2313
$\alpha_2 KL_{II}$	1.04382	2	11.8776	$\alpha_2 KL_{II}$	0.9841	1	12.598	$\zeta_2 M_{IV}N_{II}$	127.8	2	0.0970				
$\alpha_1 KL_{III}$	1.03974	2	11.9242	$\alpha_1 KL_{III}$	0.9801	1	12.649	$M_{IV}N_{III}$	126.8	2	0.0978				
$\beta_3 KM_{II}$	0.93327	5	13.2845	$\beta_3 KM_{II}$	0.8790	1	14.104	$\zeta_2 M_{IV}N_{II,III}$					108.0	2	0.1148
$\beta_1 KM_{III}$	0.93279	2	13.2914	$\beta_1 KM_{III}$	0.8785	1	14.112	$\zeta_1 M_{V}N_{III}$	128.7	2	0.0964		108.7	1	0.1140
$\beta_2 KN_{II,III}$	0.92046	2	13.4695	$\beta_2 KN_{II,III}$	0.8661	1	14.315	39 Yttrium				40 Zirconium			
$\beta_5 KM_{IV,V}$	0.9255	1	13.396	$\beta_5 KM_{IV,V}$	0.8708	2	14.238	$\alpha_2 KL_{II}$	0.83305	1	14.8829		0.79015	1	15.6909
$\beta_4 KN_{IV,V}$				$\beta_4 KN_{IV,V}$	0.8653	2	14.328	$\alpha_1 KL_{III}$	0.82884	1	14.9584		0.78593	1	15.7751
$\beta_4 L_{II}M_{II}$				$\beta_4 L_{II}M_{II}$	7.304	5	1.697	$\beta_3 KM_{II}$	0.74126	3	16.7258		0.70228	4	17.654
$\beta_3 L_{II}M_{III}$				$\beta_3 L_{II}M_{III}$	7.264	5	1.707	$\beta_3 KM_{III}$	0.74072	2	16.7378		0.70173	3	17.6678
								$\beta_2 KN_{II,III}$	0.72864	4	17.0154		0.68993	4	17.970
								$\beta_5 KM_{IV,V}$	0.7345	1	16.879		0.6959	1	17.815

TABLE 1.1A. (continued)

Designation	Å*	p.e.	keV	Å*	p.e.	keV	Designation	Å*	p.e.	keV	Å*	p.e.	keV		
39 Yttrium (Cont.)						40 Zirconium (Cont.)		43 Technetium				44 Ruthenium			
$\beta_4 KN_{IV,V}$	0.72776	5	17.036	0.68901	5	17.994	$\alpha_2 KL_{II}$	0.67932 [†]	3	18.2508	0.647408	5	19.1504		
$\beta_4 L_I M_{II}$	6.0186	3	2.0600	5.6681	3	2.1873	$\alpha_1 KL_{III}$	0.67502 [†]	3	18.3671	0.643083	4	19.2792		
$\beta_3 L_I M_{III}$	5.9832	3	2.0722	5.6330	3	2.2010	$\beta_3 KM_{II}^{\dagger}$	0.60188 [†]	4	20.599	0.573067	4	21.6346		
$\gamma_{2,3} L_I N_{II,III}$	5.2830	3	2.3468	4.9536	3	2.5029	$\beta_1 KM_{III}$	0.60130 [†]	4	20.619	0.572482	4	21.6568		
$\eta L_{II} M_I$	7.0406	3	1.76095	6.6069	3	1.87654	$\beta_2 KN_{II,III}$	0.59024 [†]	5	21.005	0.56166	3	22.074		
$\beta_1 L_{II} M_{IV}$	6.2120	3	1.99584	5.8360	3	2.1244	$\beta_5^{II} KM_{IV}$				0.5680	2	21.829		
$\gamma_5 L_{II} N_I$	5.8754	3	2.1102	5.4977	3	2.2551	$\beta_5^I KM_V$				0.56785	9	21.834		
$\gamma_1 L_{II} N_{IV}$				5.3843	3	2.3027	β_4				0.56089	9	22.104		
$l L_{III} M_I$	7.3563	3	1.68536	6.9185	3	1.79201	$\beta_4 L_{II} M_{IV}$				4.5230	2	2.7411		
$\alpha_2 L_{III} M_{IV}$	6.4558	3	1.92047	6.0778	3	2.0399	$\beta_3 L_I M_{III}$				4.4866	3	2.7634		
$\alpha_1 L_{III} M_V$	6.4488	2	1.92256	6.0705	2	2.04236	$\gamma_{2,3} L_I N_{II,III}$				3.8977	2	3.1809		
$\beta_6 L_{III} N_I$	6.0942	3	2.0344	5.7101	3	2.1712	$\eta L_{II} M_I$				5.2050	2	2.38197		
$\beta_{2,16}$				5.5863	3	2.2194	$\beta_1 L_{II} M_{IV}$	4.8873 [†]	8	2.5368	4.62058	3	2.68323		
$M_{II} M_{IV}$	81.5	2	0.1522	76.7	2	0.1617	$\gamma_5 L_{II} N_I$				4.2873	2	2.8918		
$M_{II} N_I$	46.48	9	0.267				$\gamma_1 L_{II} N_{IV}$				4.1822	2	2.9645		
$M_{III} M_V$				80.9	3	0.1533	$l L_{III} M_I$				5.5035	3	2.2528		
$M_{III} N_I$	48.5	2	0.256				$\alpha_2 L_{III} M_{IV}$				4.85381	7	2.55431		
$M_{III} M_{IV,V}$	86.5	2	0.1434				$\alpha_1 L_{III} M_V$	5.1148 [†]	3	2.4240	4.84575	5	2.55855		
$\zeta M_{IV,V} N_{II,III}$	93.4	2	0.1328	82.1	2	0.1511	$\beta_6 L_{III} N_I$				4.4866	3	2.7634		
$M_{IV,V} O_{II,III}$				70.0	4	0.177	$\beta_{2,16} L_{III} N_{IV,V}$				4.3718	2	2.8360		
41 Niobium						42 Molybdenum		45 Rhodium				46 Palladium			
$\alpha_2 KL_{II}$	0.75044	1	16.5210	0.713590	6	17.3743	$M_{II} M_{IV}$				62.2	1	0.1992		
$\alpha_1 KL_{III}$	0.74620	1	16.6151	0.709300	1	17.47934	$M_{II} N_I$				32.3	2	0.384		
$\beta_3 KM_{II}$	0.66634	3	18.6063	0.632872	9	19.5903	$M_{II} N_{IV}$				25.50	9	0.486		
$\beta_1 KM_{III}$	0.66576	2	18.6225	0.632288	9	19.6083	$M_{III} M_V$				68.3	1	0.1814		
β_2^{II}				0.62107	5	19.963	$\gamma M_{III} N_{IV,V}$				26.9	1	0.462		
$\beta_2 KN_{II,III}$	0.65416	4	18.953	0.62099	2	19.9652	$\zeta M_{IV,V} N_{II,III}$				52.34	7	0.2369		
$\beta_4 KN_{IV,V}$	0.65318	5	18.981				$M_{IV,V} O_{II,III}$				44.8	1	0.2768		
$\beta_5^{II} KM_{IV}$				0.62708	5	19.771									
$\beta_5^I KM_V$				0.62692	5	19.776									

TABLE 1.1A (continued)

X-ray Wavelengths in Å* Units and in keV. The Probable Error (p.e.) is the Error in the Last Digit of the Wavelength

Designation	Å*	p.e.	keV	Designation	Å*	p.e.	keV	Designation	Å*	p.e.	keV	Designation	Å*	p.e.	keV
45 Rhodium (Cont.)				46 Palladium (Cont.)				49 Indium (Cont.)				50 Tin (Cont.)			
$\beta_9 L_I M_V$				3.7920	2	3.2696		$\beta_1 K M_{III}$	0.454545	4	27.2759	0.435236	5	28.4860	
$M_I N_{II,III}$				20.1	2	0.616		$\beta_2 K N_{II,III}$	0.44500	1	27.8608	0.425915	8	29.1093	
$M_{II} M_{IV}$	59.3	1	0.2090	56.5	1	0.2194		$K O_{II,III}$	0.44374	3	27.940	0.42467	3	29.195	
$M_{II} N_I$	28.1	2	0.442	26.2	2	0.474		$\beta_6^{II} K M_{IV}$	0.45098	2	27.491	0.43184	3	28.710	
$M_I N_{IV}$				22.1	1	0.560		$\beta_6^I K M_V$	0.45086	2	27.499	0.43175	3	28.716	
$M_{III} M_V$	65.5	1	0.1892	62.9	1	0.1970		$\beta_4 K N_{IV,V}$	0.44393	4	27.928	0.42495	3	29.175	
$M_{III} N_I$	29.8	1	0.417	27.9	1	0.445		$\beta_4 L_I M_{II}$	3.50697	9	3.5353	3.34335	9	3.7083	
$\gamma M_{III} N_{IV,V}$	25.01	9	0.496	23.3 [†]	1	0.531		$\beta_3 L_I M_{III}$	3.46984	9	3.5731	3.30585	3	3.7500	
$\zeta M_{IV,V} N_{II,III}$	47.67	9	0.2601	43.6	1	0.2844		$\gamma_{2,3} L_I N_{II,III}$	2.9800	2	4.1605	2.8327	2	4.3768	
$M_{IV,V} O_{II,III}$	40.9	2	0.303	37.4	2	0.332		$\gamma_4 L_I O_{II,III}$	2.9264	2	4.2367	2.7775	2	4.4638	
47 Silver				48 Cadmium				$\eta L_{II} M_I$	3.98327	9	3.11254	3.78876	9	3.27234	
$\alpha_2 K L_{II}$	0.563798	4	21.9903	0.539422	3	22.9841		$\beta_1 L_{II} M_{IV}$	3.55531	4	3.48721	3.38487	3	3.66280	
$\alpha_1 K L_{III}$	0.5594075	6	22.16292	0.535010	3	23.1736		$\gamma_5 L_{II} N_I$	3.24907	9	3.8159	3.08475	9	4.0192	
$\beta_3 K M_{II}$	0.497685	4	24.9115	0.475730	5	26.0612		$\gamma_1 L_{II} N_{IV}$	3.16213	4	3.92081	3.00115	3	4.13112	
$\beta_1 K M_{III}$	0.497069	4	24.9424	0.475105	6	26.0955		$l L_{III} M_I$	4.26873	9	2.90440	4.07165	9	3.04499	
$\beta_2 K N_{II,III}$	0.487032	4	25.4564	0.465328	7	26.6438		$\alpha_2 L_{III} M_{IV}$	3.78073	6	3.27929	3.60891	4	3.43542	
$\beta_5 K M_{IV,V}$	0.49306	2	25.145					$\alpha_1 L_{III} M_V$	3.77192	4	3.28694	3.59994	3	3.44398	
$\beta_4 K N_{IV,V}$	0.48598	3	25.512					$\beta_5 L_{III} N_I$	3.43606	9	3.60823	3.26901	9	3.7926	
$\beta_4 L_I M_{II}$	3.87023	5	3.20346	3.68203	9	3.36719		$\beta_{2,15} L_{III} N_{IV,V}$	3.33838	3	3.71381	3.17505	3	3.90486	
$\beta_2 L_I M_{III}$	3.83313	9	3.23446	3.64495	9	3.40145		$\beta_7 L_{III} O_I$	3.324	4	3.730	3.1564	3	3.9279	
$\gamma_2 L_I N_{II}$	3.31216	9	3.7432	3.1377	2	3.9513		$\beta_{10} L_I M_{IV}$	3.27404	9	3.7868	3.12170	9	3.9716	
$\gamma_3 L_I N_{III}$	3.30635	9	3.7498					$\beta_9 L_I M_V$	3.26763	9	3.7942	3.11513	9	3.9800	
$\eta L_{II} M_I$	4.4183	2	2.8061	4.19315	9	2.95675		$M_{II} M_{IV}$				47.3	1	0.2621	
$\beta_1 L_{II} M_{IV}$	3.93473	3	3.15094	3.73823	4	3.31657		$M_{II} N_I$				20.0	1	0.619	
$\gamma_5 L_{II} N_I$	3.61638	9	3.42832	3.42551	9	3.61935		$M_{II} N_{IV}$				16.93	5	0.733	
$\gamma_1 L_{II} N_{IV}$	3.52260	4	3.51959	3.33564	6	3.71686		$M_{III} M_V$				54.2	1	0.2287	
$l L_{III} M_I$	4.7076	2	2.6337	4.48014	9	2.76735		$M_{III} N_I$				21.5	1	0.575	
$\alpha_2 L_{III} M_{IV}$	4.16294	5	2.97821	3.96496	6	3.12691		$\gamma M_{III} N_{IV,V}$				17.94	5	0.691	
$\alpha_1 L_{III} M_V$	4.15443	3	2.98431	3.95635	4	3.13373		$M_{IV} O_{II,III}$				25.3	1	0.491	
$\beta_5 L_{III} N_I$	3.80774	9	3.25603	3.61467	9	3.42994		$\zeta M_{IV,V} N_{II,III}$				31.24	9	0.397	
$\beta_{2,15} L_{III} N_{IV,V}$	3.70335	3	3.34781	3.51408	4	3.52812		$M_V O_{III}$				25.7	1	0.483	
$\beta_{10} L_I M_{IV}$	3.61158	9	3.43287	3.4367	2	3.6075		51 Antimony				52 Tellurium			
$\beta_9 L_I M_V$	3.60497	9	3.43917	3.43015	9	3.61445		$\alpha_2 K L_{II}$	0.474827	3	26.1108	0.455784	3	27.2017	
$M_I N_{II,III}$	18.8	2	0.658					$\alpha_1 K L_{III}$	0.470354	3	26.3591	0.451295	3	27.4723	
$M_{II} M_{IV}$	54.0	1	0.2295	52.0	2	0.2384		$\beta_3 K M_{II}$	0.417737	4	29.6792	0.400659	4	30.9443	
$M_{II} N_I$				22.9	2	0.540		$\beta_1 K M_{III}$	0.417085	3	29.7256	0.399995	5	30.9957	
$M_{II} N_{IV}$	20.66	7	0.600	19.40	7	0.639		$\beta_2 K N_{II,III}$	0.407973	5	30.3895	0.391102	6	31.7004	
$M_{III} M_V$	60.5	1	0.2048	58.7	2	0.2111		$K O_{II,III}$	0.40666	1	30.4875	0.38974	1	31.8114	
$M_{III} N_I$	26.0	1	0.478	24.5	1	0.507		$\beta_6^{II} K M_{IV}$	0.41388	1	29.9560				
$\gamma M_{III} N_{IV,V}$	21.82	7	0.568	20.47	7	0.606		$\beta_6^I K M_V$	0.41378	1	29.9632				
$M_{IV} O_{II,III}$				30.4	1	0.408		$\beta_4 K N_{IV,V}$	0.40702	1	30.4604				
$\zeta M_{IV,V} N_{II,III}$	39.77	7	0.3117	36.8	1	0.3371		$\beta_4 L_I M_{II}$	3.19014	9	3.8864	3.04661	9	4.0695	
$M_V N_I$	24.4	2	0.509					$\beta_3 L_I M_{III}$	3.15258	9	3.9327	3.00893	9	4.1204	
$M_V O_{III}$				30.8	1	0.403		$\gamma_{2,3} L_I N_{II,III}$	2.6953	2	4.5999	2.5674	2	4.8290	
$M_{IV,V} O_{II,III}$	33.5	3	0.370					$\gamma_4 L_I O_{II,III}$	2.6398	2	4.6967	2.5113	2	4.9369	
49 Indium				50 Tin				$\eta L_{II} M_I$	3.60765	9	3.43661	3.43832	9	3.60586	
$\alpha_2 K L_{II}$	0.516544	3	24.0020	0.495053	3	25.0440		$\beta_1 L_{II} M_{IV}$	3.22567	4	3.84357	3.07677	6	4.02958	
$\alpha_1 K L_{III}$	0.512113	3	24.2097	0.490599	3	25.2713		$\gamma_5 L_{II} N_I$	2.93187	9	4.2287	2.79007	9	4.4437	
$\beta_3 K M_{II}$	0.455181	4	27.2377	0.435877	5	28.4440		$\gamma_1 L_{II} N_{IV}$	2.85159	3	4.34779	2.71241	6	4.5709	
								$l L_{III} M_I$	3.88826	9	3.18860	3.71696	9	3.33555	
								$\alpha_2 L_{III} M_{IV}$	3.44840	6	3.59532	3.29846	9	3.7588	