

# INTERNATIONAL TABLES FOR X-RAY CRYSTALLOGRAPHY

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VOL. II. MATHEMATICAL TABLES  
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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 In particular, many of the physical and chemical data appearing in Volume III have been superseded.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    |

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## 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 ( $10^{-10} \text{ m}$ ) which is equivalent to the uncertainty in the absolute determination of the wavelength of  $Cu K\alpha_1$ , hence to the uncertainty in  $A$ , the conversion constant from X-units to ångströms. Bearden adopted a value for  $A$  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  $A$  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  $A$  is revised, the wavelength values in Table 1.1A and 1.1B must be multiplied by  $(A/1.002056)$  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  $A$ . 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).

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     | Å*      | p.e. | keV          | Designation                    | Å*                             | p.e.     | keV     | Å*          | p.e.               | keV     |         |
|----------------------------|---------|------|---------|---------|------|--------------|--------------------------------|--------------------------------|----------|---------|-------------|--------------------|---------|---------|
| 3 Lithium                  |         |      |         |         |      | 4 Beryllium  |                                | 19 Potassium (Cont.)           |          |         |             | 20 Calcium (Cont.) |         |         |
| $\alpha KL$                | 228.    | 1    | 0.0543  | 114.    | 1    | 0.1085       | $\eta L_{II}M_I$               | 47.24                          | 2        | 0.2625  | 40.46       | 2                  | 0.3064  |         |
| 5 Boron                    |         |      |         |         |      | 6 Carbon     |                                | $\beta_1$                      |          |         | 35.94       | 2                  | 0.3449  |         |
| $\alpha KL$                | 67.6    | 3    | 0.1833  | 44.7    | 3    | 0.277        | $i L_{III}M_I$                 | 47.74                          | 1        | 0.25971 | 40.96       | 2                  | 0.3027  |         |
| 7 Nitrogen                 |         |      |         |         |      | 8 Oxygen     |                                | $\alpha_{1,2} L_{III}M_{IV,V}$ |          |         | 36.33       | 2                  | 0.3413  |         |
| $\alpha KL$                | 31.6    | 4    | 0.3924  | 23.62   | 3    | 0.5249       | $M_{II,III}N_I$                | 692                            | 9        | 0.0179  | 525.        | 9                  | 0.0236  |         |
| 9 Fluorine                 |         |      |         |         |      | 10 Neon      |                                | 21 Scandium                    |          |         |             | 22 Titanium        |         |         |
| $\alpha_{1,2} KL_{II,III}$ | 18.32   | 2    | 0.6768  | 14.610  | 3    | 0.8486       | $\alpha_1 KL_{II}$             | 3.0342                         | 1        | 4.0861  | 2.75216     | 2                  | 4.50486 |         |
| $\beta KM$                 |         |      |         | 14.452  | 5    | 0.8579       | $\alpha_1 KL_{III}$            | 3.0309†                        | 1        | 4.0906  | 2.74851     | 2                  | 4.51084 |         |
| 11 Sodium                  |         |      |         |         |      | 12 Magnesium |                                | $\beta_{1,2} KM_{II,III}$      | 2.7796   | 2       | 4.4605      | 2.51391            | 2       | 4.93181 |
| $\alpha_{1,2} KL_{II,III}$ | 11.9101 | 9    | 1.0410  | 9.8900  | 2    | 1.25360      | $\beta_2 KM_{IV,V}$            | 2.7634                         | 3        | 4.4865  | 2.4985      | 2                  | 4.9623  |         |
| $\beta KM$                 | 11.575  | 2    | 1.0711  | 9.521   | 2    | 1.3022       | $\eta L_{II}M_I$               | 35.13                          | 2        | 0.3529  | 30.89       | 3                  | 0.4013  |         |
| $L_{II,III}M$              | 407.1   | 5    | 0.03045 | 251.5   | 5    | 0.0493       | $\beta_1 L_{III}M_{IV}$        | 31.02                          | 2        | 0.3996  | 27.05       | 2                  | 0.4584  |         |
| $L_I L_{II,III}$           | 376     | 1    | 0.0330  | 317     | 1    | 0.0392       | $i L_{III}M_I$                 | 35.59                          | 3        | 0.3483  | 31.36       | 2                  | 0.3953  |         |
| 13 Aluminum                |         |      |         |         |      | 14 Silicon   |                                | $\alpha_{1,2} L_{III}M_{IV,V}$ | 31.35    | 3       | 0.3954      | 27.42              | 2       | 0.4522  |
| $\alpha_2 KL_{II}$         | 8.34173 | 9    | 1.48627 | 7.12791 | 9    | 1.73938      | 23 Vanadium                    |                                |          |         | 24 Chromium |                    |         |         |
| $\alpha_1 KL_{III}$        | 8.33934 | 9    | 1.48670 | 7.12542 | 9    | 1.73998      | $\alpha_2 KL_{II}$             | 2.50738                        | 2        | 4.94464 | 2.293606    | 3                  | 5.40551 |         |
| $\beta KM$                 | 7.960   | 2    | 1.5574  | 6.753   | 1    | 1.8359       | $\alpha_1 KL_{III}$            | 2.50356                        | 2        | 4.95220 | 2.28970     | 2                  | 5.41472 |         |
| $L_{II,III}$               | 171.4   | 5    | 0.0724  | 135.5   | 4    | 0.0915       | $\beta_{1,2} KM_{II,III}$      | 2.28440                        | 2        | 5.42729 | 2.08487     | 2                  | 5.94671 |         |
| $L_I L_{II,III}$           | 290.    | 1    | 0.0428  |         |      |              | $\beta_2 KM_{IV,V}$            | 2.26951                        | 6        | 5.4629  | 2.07087     | 6                  | 5.9869  |         |
| 15 Phosphorus              |         |      |         |         |      | 16 Sulfur    |                                | $\beta_{2,4} L_I M_{II,III}$   | 21.19†   | 9       | 0.585       | 18.96              | 2       | 0.654   |
| $\alpha_2 KL_{II}$         | 6.160†  | 1    | 2.0127  | 5.37496 | 8    | 2.30664      | $\eta L_{II}M_I$               | 27.34                          | 3        | 0.4535  | 24.30       | 3                  | 0.5102  |         |
| $\alpha_1 KL_{III}$        | 6.157†  | 1    | 2.0137  | 5.37216 | 7    | 2.30784      | $\beta_1 L_{III}M_{IV}$        | 23.88                          | 4        | 0.5192  | 21.27       | 1                  | 0.5828  |         |
| $\beta KM$                 | 5.796   | 2    | 2.1390  |         |      |              | $i L_{III}M_I$                 | 27.77                          | 1        | 0.4465  | 24.78       | 1                  | 0.5003  |         |
| $\beta_1 KM$               |         |      |         | 5.0316  | 2    | 2.4640       | $\alpha_{1,2} L_{III}M_{IV,V}$ | 24.25                          | 3        | 0.5113  | 21.64       | 3                  | 0.5728  |         |
| $\beta_2 KM$               |         |      |         | 5.0233  | 3    | 2.4681       | $M_{II,III}M_{IV,V}$           | 337.                           | 9        | 0.037   | 309.        | 9                  | 0.040   |         |
| $L_{II,III}M$              | 103.8   | 4    | 0.1194  |         |      |              | 25 Manganese                   |                                |          |         | 26 Iron     |                    |         |         |
| $i, \eta L_{II,III}M_I$    |         |      |         | 83.4    | 3    | 0.1487       | $\alpha_2 KL_{II}$             | 2.10578                        | 2        | 5.88765 | 1.939980    | 9                  | 6.39084 |         |
| 17 Chlorine                |         |      |         |         |      | 18 Argon     |                                | $\alpha_1 KL_{III}$            | 2.101820 | 9       | 5.89875     | 1.936042           | 9       | 6.40384 |
| $\alpha_2 KL_{II}$         | 4.7307  | 1    | 2.62078 | 4.19474 | 5    | 2.95563      | $\beta_{1,2} KM_{II,III}$      | 1.91021                        | 2        | 6.49045 | 1.75661     | 2                  | 7.05798 |         |
| $\alpha_1 KL_{III}$        | 4.7278  | 1    | 2.62239 | 4.19180 | 5    | 2.95770      | $\beta_2 KM_{IV,V}$            | 1.9971                         | 1        | 6.5352  | 1.7442      | 1                  | 7.1081  |         |
| $\beta KM$                 | 4.4034  | 3    | 2.8156  |         |      |              | $\beta_{2,4} L_I M_{II,III}$   | 17.19                          | 2        | 0.721   | 15.65       | 2                  | 0.792   |         |
| $\beta_{1,2} KM_{II,III}$  |         |      |         | 3.8860  | 2    | 3.1905       | $\eta L_{II}M_I$               | 21.85                          | 2        | 0.5675  | 19.75       | 4                  | 0.628   |         |
| $\eta L_{II}M_I$           | 67.33   | 9    | 0.1841  | 55.9†   | 1    | 0.2217       | $\beta_1 L_{III}M_{IV}$        | 19.11                          | 2        | 0.6488  | 17.26       | 1                  | 0.7185  |         |
| $i L_{III}M_I$             | 67.90   | 9    | 0.1826  | 56.3†   | 1    | 0.2201       | $i L_{III}M_I$                 | 22.29                          | 1        | 0.5563  | 20.15       | 1                  | 0.6152  |         |
| 19 Potassium               |         |      |         |         |      | 20 Calcium   |                                | $\alpha_{1,2} L_{III}M_{IV,V}$ | 19.45    | 1       | 0.6374      | 17.59              | 2       | 0.7050  |
| $\alpha_2 KL_{II}$         | 3.7445  | 2    | 3.3111  | 3.36166 | 3    | 3.68809      | $M_{II,III}M_{IV,V}$           | 273.                           | 6        | 0.045   | 243.        | 5                  | 0.051   |         |
| $\alpha_1 KL_{III}$        | 3.7414  | 2    | 3.3138  | 3.35839 | 3    | 3.69168      | 27 Cobalt                      |                                |          |         | 28 Nickel   |                    |         |         |
| $\beta_{1,2} KM_{II,III}$  | 3.4539  | 2    | 3.5896  | 3.0897  | 2    | 4.0†27       | $\alpha_2 KL_{II}$             | 1.792850                       | 9        | 6.91530 | 1.661747    | 8                  | 7.46089 |         |
| $\beta_2 KM_{IV,V}$        | 3.4413  | 4    | 3.6027  | 3.0746  | 3    | 4.0325       | $\alpha_1 KL_{III}$            | 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 |
|                            |         |      |         |         |      |              |                                | $\beta_2 KM_{IV,V}$            | 1.60891  | 3       | 7.7059      | 1.48862            | 4       | 8.3286  |
|                            |         |      |         |         |      |              |                                | $\beta_{2,4} L_I M_{II,III}$   | 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   |
|                            |         |      |         |         |      |              |                                | $\beta_1 L_{III}M_{IV}$        | 15.666   | 8       | 0.7914      | 14.271             | 6       | 0.8688  |
|                            |         |      |         |         |      |              |                                | $i L_{III}M_I$                 | 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  |

## 1. X-RAY WAVELENGTHS

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      | Å*       | p.e. | keV          | Designation                    | Å*                              | p.e.   | keV     | Å*      | p.e.               | keV          |        |  |
|--------------------------------|----------|------|----------|----------|------|--------------|--------------------------------|---------------------------------|--------|---------|---------|--------------------|--------------|--------|--|
| 29 Copper                      |          |      |          |          |      | 30 Zinc      |                                | 35 Bromine (Cont.)              |        |         |         | 36 Krypton (Cont.) |              |        |  |
| $\alpha_2 KL_{II}$             | 1.544390 | 2    | 8.02783  | 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  | 1.435155 | 7    | 8.63886      | $\eta L_{II}M_I$               | 9.255                           | 1      | 1.3396  |         |                    |              |        |  |
| $\beta_3 KM_{II}$              | 1.3926   | 1    | 8.9029   |          |      |              | $\beta_1 L_{III}M_{IV}$        | 8.1251                          | 5      | 1.52590 | 7.576†  | 3                  | 1.6366       |        |  |
| $\beta_{1,2} KM_{II,III}$      | 1.392218 | 9    | 8.90529  | 1.29525  | 2    | 9.5720       | $\gamma_6$                     |                                 |        |         | 7.279   | 5                  | 1.703        |        |  |
| $\beta_2 KN_{II,III}$          |          |      |          | 1.28372  | 2    | 9.6580       | $\eta L_{III}M_I$              | 9.585                           | 1      | 1.2935  |         |                    |              |        |  |
| $\beta_6 KM_{IV,V}$            | 1.38109  | 3    | 8.9770   | 1.2848   | 1    | 9.6501       | $\alpha_{1,2} L_{III}M_{IV,V}$ | 8.3746                          | 5      | 1.48043 | 7.817†  | 3                  | 1.5860       |        |  |
| $\beta_{3,4} L_{II}M_{II,III}$ | 12.122   | 8    | 1.0228   | 11.200   | 7    | 1.1070       | $\beta_6$                      |                                 |        |         | 7.510   | 4                  | 1.6510       |        |  |
| $\eta L_{II}M_I$               | 14.90    | 2    | 0.832    | 13.68    | 2    | 0.906        | $L_{II}N_{III}$                |                                 |        |         | 7.250   | 5                  | 1.710        |        |  |
| $\beta_1 L_{II}M_{IV}$         | 13.053   | 3    | 0.9498   | 11.983   | 3    | 1.0347       | $M_{II}M_{II}$                 | 184.6                           | 3      | 0.0672  |         |                    |              |        |  |
| $\eta L_{III}M_I$              | 15.286   | 9    | 0.8111   | 14.02    | 2    | 0.884        | $M_{II}M_{III}$                | 164.7                           | 3      | 0.0753  |         |                    |              |        |  |
| $\alpha_{1,2} L_{III}M_{IV,V}$ | 13.336   | 3    | 0.9297   | 12.254   | 3    | 1.0117       | $M_{II}M_{IV}$                 | 109.4                           | 3      | 0.1133  |         |                    |              |        |  |
| $M_{II,III}M_{IV,V}$           | 173.     | 3    | 0.072    | 157.     | 3    | 0.079        | $M_{II}N_I$                    | 76.9                            | 2      | 0.1610  |         |                    |              |        |  |
| 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  | 1.258011 | 9    | 9.85532      | $\xi_2 M_{IV}N_{II}$           | 191.1                           | 2      | 0.06488 |         |                    |              |        |  |
| $\alpha_1 KL_{III}$            | 1.340083 | 9    | 9.25174  | 1.254054 | 9    | 9.88642      | $M_{IV}N_{III}$                | 189.5                           | 3      | 0.0654  |         |                    |              |        |  |
| $\beta_3 KM_{II}$              | 1.20835  | 5    | 10.2603  | 1.12936  | 9    | 10.9780      | $\xi_1 M_{V}N_{III}$           | 192.6                           | 2      | 0.06437 |         |                    |              |        |  |
| $\beta_1 KM_{III}$             | 1.20789  | 2    | 10.2642  | 1.12894  | 2    | 10.9821      | 37 Rubidium                    |                                 |        |         |         |                    | 38 Strontium |        |  |
| $\beta_2 KN_{II,III}$          | 1.19600  | 2    | 10.3663  | 1.11686  | 2    | 11.1008      | $\alpha_2 KL_{II}$             | 0.92969                         | 1      | 13.3358 | 0.87943 | 1                  | 14.0979      |        |  |
| $\beta_6 KM_{IV,V}$            | 1.1981   | 2    | 10.348   | 1.1195   | 1    | 11.0745      | $\alpha_1 KL_{III}$            | 0.925553                        | 9      | 13.3953 | 0.87526 | 1                  | 14.1650      |        |  |
| $\beta_4 L_{II}M_{II}$         |          |      |          | 9.640    | 2    | 1.2861       | $\beta_3 KM_{II}$              | 0.82921                         | 3      | 14.9517 | 0.78345 | 3                  | 15.8249      |        |  |
| $\beta_3 L_{II}M_{III}$        |          |      |          | 9.581    | 2    | 1.2941       | $\beta_1 KM_{III}$             | 0.82868                         | 2      | 14.9613 | 0.78292 | 2                  | 15.8357      |        |  |
| $\beta_{3,4} L_{II}M_{II,III}$ | 10.359†  | 8    | 1.197    |          |      |              | $\beta_2 KN_{II,III}$          | 0.81645                         | 3      | 15.1854 | 0.77081 | 3                  | 16.0846      |        |  |
| $\eta L_{II}M_I$               | 12.597   | 2    | 0.9842   | 11.609   | 2    | 1.0680       | $\beta_5 KM_{IV,V}$            | 0.8219                          | 1      | 15.085  | 0.7764  | 1                  | 15.969       |        |  |
| $\beta_1 L_{II}M_{IV}$         | 11.023   | 2    | 1.1248   | 10.175   | 1    | 1.2185       | $\beta_4 KN_{IV,V}$            | 0.8154                          | 2      | 15.205  | 0.76989 | 5                  | 16.104       |        |  |
| $\eta L_{III}M_I$              | 12.953   | 2    | 0.9572   | 11.965   | 4    | 1.0362       | $\beta_4 L_{II}M_{II}$         | 6.8207                          | 3      | 1.81771 | 6.4026  | 3                  | 1.93643      |        |  |
| $\alpha_{1,2} L_{III}M_{IV,V}$ | 11.292   | 1    | 1.09792  | 10.4361  | 8    | 1.18800      | $\beta_2 L_{II}M_{III}$        | 6.7876                          | 3      | 1.82659 | 6.3672  | 3                  | 1.94719      |        |  |
| 33 Arsenic                     |          |      |          |          |      | 34 Selenium  |                                | $\gamma_{2,3} L_{II}N_{II,III}$ | 6.0458 | 3       | 2.0507  | 5.6445             | 3            | 2.1965 |  |
|                                |          |      |          |          |      |              | $\eta L_{II}M_I$               | 8.0415                          | 4      | 1.54177 | 7.5171  | 3                  | 1.64933      |        |  |
| $\alpha_2 KL_{II}$             | 1.17987  | 1    | 10.50799 | 1.10882  | 2    | 11.1814      | $\beta_1 L_{II}M_{IV}$         | 7.0759                          | 3      | 1.75217 | 6.6239  | 3                  | 1.87172      |        |  |
| $\alpha_1 KL_{III}$            | 1.17588  | 1    | 10.54372 | 1.10477  | 2    | 11.2224      | $\gamma_5 L_{II}N_{IV}$        | 6.7553                          | 3      | 1.83532 | 6.2961  | 3                  | 1.96916      |        |  |
| $\beta_3 KM_{II}$              | 1.05783  | 5    | 11.7203  | 0.99268  | 5    | 12.4896      | $\eta L_{III}M_I$              | 8.3636                          | 4      | 1.48238 | 7.8362  | 3                  | 1.58215      |        |  |
| $\beta_1 KM_{III}$             | 1.05730  | 2    | 11.7262  | 0.99218  | 3    | 12.4959      | $\alpha_2 L_{III}M_{IV}$       | 7.3251                          | 3      | 1.69256 | 6.8697  | 3                  | 1.80474      |        |  |
| $\beta_2 KN_{II,III}$          | 1.04500  | 3    | 11.8642  | 0.97992  | 5    | 12.6522      | $\alpha_1 L_{III}M_V$          | 7.3183                          | 2      | 1.69413 | 6.8628  | 2                  | 1.80656      |        |  |
| $\beta_5 KM_{IV,V}$            | 1.0488   | 1    | 11.822   | 0.9843   | 1    | 12.595       | $\beta_5 L_{III}N_I$           | 6.9842                          | 3      | 1.77517 | 6.5191  | 3                  | 1.90181      |        |  |
| $\beta_{3,4} L_{II}M_{II,III}$ | 8.929    | 1    | 1.3884   | 8.321†   | 9    | 1.490        | $M_{II}M_{III}$                | 144.4                           | 3      | 0.0859  |         |                    |              |        |  |
| $\eta L_{II}M_I$               | 10.734   | 1    | 1.1550   | 9.962    | 1    | 1.2446       | $M_{II}M_{IV}$                 | 91.5                            | 2      | 0.1355  | 85.7    | 2                  | 0.1447       |        |  |
| $\beta_1 L_{II}M_{IV}$         | 9.4141   | 8    | 1.3170   | 8.7358   | 5    | 1.41923      | $M_{II}N_I$                    | 57.0                            | 2      | 0.2174  | 51.3    | 1                  | 0.2416       |        |  |
| $\eta L_{III}M_I$              | 11.072   | 1    | 1.1198   | 10.294   | 1    | 1.2044       | $M_{III}M_{IV,V}$              | 96.7                            | 2      | 0.1282  | 91.4    | 2                  | 0.1357       |        |  |
| $\alpha_{1,2} L_{III}M_{IV,V}$ | 9.6709   | 8    | 1.2820   | 8.9900   | 5    | 1.37910      | $M_{III}N_I$                   | 59.5                            | 2      | 0.2083  | 53.6    | 1                  | 0.2313       |        |  |
| $M_VN_{III}$                   |          |      |          | 230.     | 2    | 0.0538       | $\xi_2 M_{IV}N_{II}$           | 127.8                           | 2      | 0.0970  |         |                    |              |        |  |
| 35 Bromine                     |          |      |          |          |      | 36 Krypton   |                                | $M_{IV}N_{III}$                 | 126.8  | 2       | 0.0978  |                    |              |        |  |
|                                |          |      |          |          |      |              | $\xi_2 M_{IV}N_{II,III}$       |                                 |        |         | 108.0   | 2                  | 0.1148       |        |  |
| $\alpha_2 KL_{II}$             | 1.04382  | 2    | 11.8776  | 0.9841   | 1    | 12.598       | $\xi_1 M_VN_{III}$             | 128.7                           | 2      | 0.0964  | 108.7   | 1                  | 0.1140       |        |  |
| $\alpha_1 KL_{III}$            | 1.03974  | 2    | 11.9242  | 0.9801   | 1    | 12.649       | 39 Yttrium                     |                                 |        |         |         |                    | 40 Zirconium |        |  |
| $\beta_3 KM_{II}$              | 0.93327  | 5    | 13.2845  | 0.8790   | 1    | 14.104       | $\alpha_2 KL_{II}$             | 0.83305                         | 1      | 14.8829 | 0.79015 | 1                  | 15.6909      |        |  |
| $\beta_1 KM_{III}$             | 0.93279  | 2    | 13.2914  | 0.8785   | 1    | 14.112       | $\alpha_1 KL_{III}$            | 0.82884                         | 1      | 14.9584 | 0.78593 | 1                  | 15.7751      |        |  |
| $\beta_2 KN_{II,III}$          | 0.92046  | 2    | 13.4695  | 0.8661   | 1    | 14.315       | $\beta_3 KM_{II}$              | 0.74126                         | 3      | 16.7258 | 0.70228 | 4                  | 17.654       |        |  |
| $\beta_6 KM_{IV,V}$            | 0.9255   | 1    | 13.396   | 0.8708   | 2    | 14.238       | $\beta_1 KM_{III}$             | 0.74072                         | 2      | 16.7378 | 0.70173 | 3                  | 17.6678      |        |  |
| $\beta_4 KN_{IV,V}$            |          |      |          | 0.8653   | 2    | 14.328       | $\beta_2 KN_{II,III}$          | 0.72864                         | 4      | 17.0154 | 0.68993 | 4                  | 17.970       |        |  |
| $\beta_4 L_{II}M_{II}$         |          |      |          | 7.304    | 5    | 1.697        | $\beta_6 KM_{IV,V}$            | 6.7345                          | 1      | 16.879  | 6.6959  | 1                  | 17.815       |        |  |
| $\beta_1 L_{II}M_{III}$        |          |      |          | 7.264    | 5    | 1.707        |                                |                                 |        |         |         |                    |              |        |  |

## 1. X-RAY WAVELENGTHS

**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     | 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 <sup>†</sup> | 3    | 18.2508 | 0.647408 | 5            | 19.1504 |  |  |
| $\beta_4$ $L_{II}M_{II}$          | 6.0186  | 3    | 2.0600  | 5.6681   | 3    | 2.1873               | $\alpha_1$ $KL_{III}$             | 0.67502 <sup>†</sup> | 3    | 18.3671 | 0.643083 | 4            | 19.2792 |  |  |
| $\beta_3$ $L_{II}M_{III}$         | 5.9832  | 3    | 2.0722  | 5.6330   | 3    | 2.2010               | $\beta_3$ $KM_{II}^{\dagger}$     | 0.60188 <sup>†</sup> | 4    | 20.599  | 0.573067 | 4            | 21.6346 |  |  |
| $\gamma_{2,3}$ $L_{II}N_{II,III}$ | 5.2830  | 3    | 2.3468  | 4.9536   | 3    | 2.5029               | $\beta_1$ $KM_{III}$              | 0.60130 <sup>†</sup> | 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 <sup>†</sup> | 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               | $\beta_4$                         |                      |      |         | 0.56089  | 9            | 22.104  |  |  |
| $I$ $L_{III}M_I$                  | 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               | $\beta_3$ $L_{II}M_{III}$         |                      |      |         | 4.4866   | 3            | 2.7634  |  |  |
| $\alpha_1$ $L_{III}M_V$           | 6.4488  | 2    | 1.92256 | 6.0705   | 2    | 2.04236              | $\gamma_{2,3}$ $L_{II}N_{II,III}$ |                      |      |         | 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 <sup>†</sup>  | 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               | $I$ $L_{III}M_I$                  |                      |      |         | 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 <sup>†</sup>  | 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               | $\beta_5$ $L_{III}N_I$            |                      |      |         | 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  |  |  |
| $\beta_5^{II}$                    |         |      |         | 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               |                                   |                      |      |         |          |              |         |  |  |
| $\beta_4$ $KN_{IV,V}$             |         |      |         | 0.62001  | 9    | 19.996               |                                   |                      |      |         |          |              |         |  |  |
| $\beta_4$ $L_{II}M_{II}$          | 5.3455  | 3    | 2.3194  | 5.0488   | 3    | 2.4557               | $\alpha_2$ $KL_{II}$              | 0.617630             | 4    | 20.0737 | 0.589821 | 3            | 21.0201 |  |  |
| $\beta_3$ $L_{II}M_{III}$         | 5.3102  | 3    | 2.3348  | 5.0133   | 3    | 2.4730               | $\alpha_1$ $KL_{III}$             | 0.613279             | 4    | 20.2161 | 0.585448 | 3            | 21.1771 |  |  |
| $\gamma_{2,3}$ $L_{II}N_{II,III}$ | 4.6542  | 2    | 2.6638  | 4.3800   | 2    | 2.8306               | $\beta_3$ $KM_{II}$               | 0.546200             | 4    | 22.6989 | 0.521123 | 4            | 23.7911 |  |  |
| $\eta$ $L_{II}M_I$                | 6.2109  | 3    | 1.99620 | 5.8475   | 3    | 2.1202               | $\beta_1$ $KM_{III}$              | 0.545605             | 4    | 22.7236 | 0.520520 | 4            | 23.8187 |  |  |
| $\beta_1$ $L_{II}M_{IV}$          | 5.4923  | 3    | 2.2574  | 5.17708  | 8    | 2.39481              | $\beta_2^{II}$ $KN_{II}$          | 0.53513              | 5    | 23.168  |          |              |         |  |  |
| $\gamma_5$ $L_{II}N_I$            | 5.1517  | 3    | 2.4066  | 4.8369   | 2    | 2.5632               | $\beta_2$ $KN_{II,III}$           | 0.53503              | 2    | 23.1728 | 0.510228 | 4            | 24.2991 |  |  |
| $\gamma_1$ $L_{II}N_{IV}$         | 5.0361  | 3    | 2.4618  | 4.7258   | 2    | 2.6235               | $\beta_5^{II}$ $KM_{IV}$          | 0.54118              | 9    | 22.909  |          |              |         |  |  |
| $I$ $L_{III}M_I$                  | 6.5176  | 3    | 1.90225 | 6.1508   | 3    | 2.01568              | $\beta_5^I$ $KM_V$                | 0.54101              | 9    | 22.917  |          |              |         |  |  |
| $\alpha_2$ $L_{III}M_{IV}$        | 5.7319  | 3    | 2.1630  | 5.41437  | 8    | 2.28985              | $\beta_4$ $KN_{IV,V}$             | 0.53401              | 9    | 23.217  | 0.5093   | 2            | 24.346  |  |  |
| $\alpha_1$ $L_{III}M_V$           | 5.7243  | 2    | 2.16589 | 5.40655  | 8    | 2.29316              | $\beta_5$ $KM_{IV,V}$             |                      |      |         | 0.51670  | 9            | 23.995  |  |  |
| $\beta_6$ $L_{III}N_I$            | 5.3613  | 3    | 2.3125  | 5.0488   | 5    | 2.4557               | $\beta_4$ $L_{II}M_{II}$          | 4.2888               | 2    | 2.8908  | 4.0711   | 2            | 3.0454  |  |  |
| $\beta_{2,16}$ $L_{III}N_{IV,V}$  | 5.2379  | 3    | 2.3670  | 4.9232   | 2    | 2.5183               | $\beta_3$ $L_{II}M_{III}$         | 4.2522               | 2    | 2.9157  | 4.0346   | 2            | 3.0730  |  |  |
| $M_{II}M_{IV}$                    | 72.1    | 3    | 0.1718  | 68.9     | 2    | 0.1798               | $\gamma_{2,3}$ $L_{II}N_{II,III}$ | 3.6855               | 2    | 3.3640  | 3.4892   | 2            | 3.5533  |  |  |
| $M_{II}N_I$                       | 38.4    | 3    | 0.323   | 35.3     | 3    | 0.351                | $\eta$ $L_{II}M_I$                | 4.9217               | 2    | 2.5191  | 4.6605   | 2            | 2.6603  |  |  |
| $M_{II}N_{IV}$                    | 33.1    | 2    | 0.375   |          |      |                      | $\beta_1$ $L_{II}M_{IV}$          | 4.37414              | 4    | 2.83441 | 4.14622  | 5            | 2.99022 |  |  |
| $M_{III}M_V$                      | 78.4    | 2    | 0.1582  | 74.9     | 1    | 0.1656               | $\gamma_5$ $L_{II}N_I$            | 4.0451               | 2    | 3.0650  | 3.8222   | 2            | 3.2437  |  |  |
| $M_{III}N_I$                      | 40.7    | 2    | 0.305   | 37.5     | 2    | 0.331                | $\gamma_1$ $L_{II}N_{IV}$         | 3.9437               | 2    | 3.1438  | 3.7246   | 2            | 3.3287  |  |  |
| $\gamma$ $M_{III}N_{IV,V}$        | 34.9    | 2    | 0.356   |          |      |                      | $I$ $L_{III}M_I$                  | 5.2169               | 3    | 2.3765  | 4.9525   | 3            | 2.5034  |  |  |
| $\zeta$ $M_{IV,V}N_{II,III}$      | 72.19   | 9    | 0.1717  | 64.38    | 7    | 0.1926               | $\alpha_2$ $L_{III}M_{IV}$        | 4.60545              | 9    | 2.69205 | 4.37588  | 7            | 2.83329 |  |  |
| $M_{IV,V}O_{II,III}$              | 61.9    | 2    | 0.2002  | 54.8     | 2    | 0.2262               | $\alpha_1$ $L_{III}M_V$           | 4.59743              | 9    | 2.69674 | 4.36767  | 5            | 2.83861 |  |  |
|                                   |         |      |         |          |      |                      | $\beta_5$ $L_{III}N_I$            | 4.2417               | 2    | 2.9229  | 4.0162   | 2            | 3.0870  |  |  |
|                                   |         |      |         |          |      |                      | $\beta_{2,16}$ $L_{III}N_{IV,V}$  | 4.1310               | 2    | 3.0013  | 3.90887  | 4            | 3.17179 |  |  |
|                                   |         |      |         |          |      |                      | $\beta_{10}$ $L_{II}M_{IV}$       |                      |      |         | 3.7988   | 2            | 3.2637  |  |  |

1. X-RAY WAVELENGTHS

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

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     | Å*                   | p.e. | keV                  | Designation                    | Å*                      | p.e.   | keV     | Å*        | p.e.              | keV     |        |
|--------------------------------|----------------------|------|---------|----------------------|------|----------------------|--------------------------------|-------------------------|--------|---------|-----------|-------------------|---------|--------|
| 51 Antimony (Cont.)            |                      |      |         |                      |      | 52 Tellurium (Cont.) |                                | 55 Cesium (Cont.)       |        |         |           | 56 Barium (Cont.) |         |        |
| $\alpha_1 L_{III}M_V$          | 3.43941              | 4    | 3.60472 | 3.28920              | 6    | 3.76933              | $\gamma_4 L_{II}O_{II,III}$    | 2.1741                  | 2      | 5.7026  | 2.0756    | 3                 | 5.9733  |        |
| $\beta_6 L_{III}N_I$           | 3.11513              | 9    | 3.9800  | 2.97088              | 9    | 4.1732               | $\eta L_{II}M_I$               | 2.9932                  | 2      | 4.1421  | 2.8627    | 3                 | 4.3309  |        |
| $\beta_{2,15} L_{III}N_{IV,V}$ | 3.02335              | 3    | 4.10078 | 2.88217              | 8    | 4.3017               | $\beta_1 L_{II}M_{IV}$         | 2.6837                  | 2      | 4.6198  | 2.56821   | 5                 | 4.82753 |        |
| $\beta_7 L_{III}O_I$           | 3.0052               | 3    | 4.1255  | 2.8634               | 3    | 4.3298               | $\gamma_5 L_{II}N_I$           | 2.4174                  | 2      | 5.1287  | 2.3085    | 3                 | 5.3707  |        |
| $\beta_{10} L_I M_{IV}$        | 2.97917              | 9    | 4.1616  | 2.84679              | 9    | 4.3551               | $\gamma_1 L_{II}N_{IV}$        | 2.3480                  | 2      | 5.2804  | 2.2415    | 2                 | 5.5311  |        |
| $\beta_9 L_I M_V$              | 2.97261              | 9    | 4.1708  | 2.83897              | 9    | 4.3671               | $\beta_1 L_{III}M_I$           | 3.2670                  | 2      | 3.7950  | 3.1355    | 2                 | 3.9541  |        |
| $M_{II}M_{IV}$                 | 45.2                 | 1    | 0.2743  |                      |      |                      | $\alpha_2 L_{III}M_{IV}$       | 2.9020                  | 2      | 4.2722  | 2.78553   | 5                 | 4.45090 |        |
| $M_{II}N_I$                    | 18.8                 | 1    | 0.658   | 17.6                 | 1    | 0.703                | $\alpha_1 L_{III}M_V$          | 2.8924                  | 2      | 4.2865  | 2.77595   | 5                 | 4.46626 |        |
| $M_{II}N_{IV}$                 | 15.98                | 5    | 0.776   |                      |      |                      | $\beta_6 L_{III}N_I$           | 2.5932                  | 2      | 4.7811  | 2.4826    | 2                 | 4.9939  |        |
| $M_{III}M_V$                   | 52.2                 | 1    | 0.2375  | 50.3                 | 1    | 0.2465               | $\beta_{2,15} L_{III}N_{IV,V}$ | 2.5118                  | 2      | 4.9359  | 2.40435   | 6                 | 5.1565  |        |
| $M_{III}N_I$                   | 20.2                 | 1    | 0.612   | 19.1                 | 1    | 0.648                | $\beta_7 L_{III}O_I$           | 2.4849                  | 2      | 4.9893  | 2.3806    | 2                 | 5.2079  |        |
| $\gamma M_{III}N_{IV,V}$       | 16.92                | 4    | 0.733   | 15.93                | 4    | 0.778                | $\beta_{10} L_I M_{IV}$        | 2.4920                  | 2      | 4.9752  | 2.3869    | 2                 | 5.1941  |        |
| $M_{IV}O_{II,III}$             |                      |      |         | 21.34                | 5    | 0.581                | $\beta_8 L_I M_V$              | 2.4783                  | 2      | 5.0026  | 2.3764    | 2                 | 5.2171  |        |
| $\zeta M_{IV,V}N_{II,III}$     | 28.88                | 8    | 0.429   | 26.72                | 9    | 0.464                | $\gamma M_{III}N_{IV,V}$       |                         |        |         | 12.75     | 3                 | 0.973   |        |
| $M_V O_{III}$                  |                      |      |         | 21.78                | 5    | 0.569                | $M_{IV}O_{II}$                 |                         |        |         | 15.91     | 5                 | 0.779   |        |
|                                |                      |      |         |                      |      |                      | $M_{IV}O_{III}$                |                         |        |         | 15.72     | 9                 | 0.789   |        |
| 53 Iodine                      |                      |      |         |                      |      | 54 Xenon             |                                |                         |        |         | 20.64     | 4                 | 0.601   |        |
|                                |                      |      |         |                      |      |                      |                                |                         |        |         | 16.20     | 5                 | 0.765   |        |
| $\alpha_2 K L_{II}$            | 0.437829             | 7    | 28.3172 | 0.42087 <sup>†</sup> | 2    | 29.458               | $N_{IV}O_{II}$                 | 188.6                   | 1      | 0.06574 | 163.3     | 2                 | 0.07590 |        |
| $\alpha_1 K L_{III}$           | 0.433318             | 5    | 28.6120 | 0.41634 <sup>†</sup> | 2    | 29.779               | $N_{IV}O_{III}$                | 183.8                   | 1      | 0.06746 | 159.0     | 2                 | 0.07796 |        |
| $\beta_3 K M_{II}$             | 0.384564             | 4    | 32.2394 | 0.36941 <sup>†</sup> | 2    | 33.562               | $N_V O_{III}$                  | 190.3                   | 1      | 0.06515 | 164.6     | 2                 | 0.07530 |        |
| $\beta_1 K M_{III}$            | 0.383905             | 4    | 32.2947 | 0.36872 <sup>†</sup> | 2    | 33.624               |                                |                         |        |         |           |                   |         |        |
| $\alpha_2 K N_{II,III}$        | 0.37523 <sup>†</sup> | 2    | 33.042  | 0.36026 <sup>†</sup> | 3    | 34.415               | 57 Lanthanum                   |                         |        |         | 58 Cerium |                   |         |        |
| $\beta_4 L_I M_{II}$           | 2.91207              | 9    | 4.2575  |                      |      |                      | $\alpha_2 K L_{II}$            | 0.375313                | 2      | 33.0341 | 0.361683  | 2                 | 34.2789 |        |
| $\beta_5 L_I M_{III}$          | 2.87429              | 9    | 4.3134  |                      |      |                      | $\alpha_1 K L_{III}$           | 0.370737                | 2      | 33.4418 | 0.357092  | 2                 | 34.7197 |        |
| $\gamma_{2,3} L_I N_{II,III}$  | 2.4475               | 2    | 5.0657  |                      |      |                      | $\beta_3 K M_{II}$             | 0.328686                | 4      | 37.7202 | 0.316520  | 4                 | 39.1701 |        |
| $\gamma_4 L_I O_{II,III}$      | 2.3913               | 2    | 5.1848  |                      |      |                      | $\beta_1 K M_{III}$            | 0.327983                | 3      | 37.8010 | 0.315816  | 2                 | 39.2573 |        |
| $\eta L_{II}M_I$               | 3.27979              | 9    | 3.7801  |                      |      |                      | $\beta_2 K N_{II,III}$         | 0.320117                | 7      | 38.7299 | 0.30816   | 1                 | 40.233  |        |
| $\beta_1 L_{II}M_{IV}$         | 2.93744              | 6    | 4.22072 |                      |      |                      | $K O_{II,III}$                 | 0.31864                 | 2      | 38.909  | 0.30668   | 2                 | 40.427  |        |
| $\gamma_5 L_{II}N_I$           | 2.65710              | 9    | 4.6660  |                      |      |                      | $\beta_5^{II} K M_{IV}$        | 0.32563                 | 2      | 38.074  | 0.31357   | 2                 | 39.539  |        |
| $\gamma_1 L_{II}N_{IV}$        | 2.58244              | 8    | 4.8009  |                      |      |                      | $\beta_5^I K M_V$              | 0.32546                 | 2      | 38.094  | 0.31342   | 2                 | 39.558  |        |
| $\beta_1 L_{III}M_I$           | 3.55754              | 9    | 3.48502 |                      |      |                      | $\beta_4 K N_{IV,V}$           | 0.31931                 | 2      | 38.828  | 0.30737   | 2                 | 40.337  |        |
| $\alpha_2 L_{III}M_{IV}$       | 3.15791              | 6    | 3.92604 |                      |      |                      | $\beta_4 L_I M_{II}$           | 2.4493                  | 3      | 5.0620  | 2.3497    | 4                 | 5.2765  |        |
| $\alpha_1 L_{III}M_V$          | 3.14860              | 6    | 3.93765 | 3.0166 <sup>†</sup>  | 2    | 4.1099               | $\beta_5 L_I M_{III}$          | 2.4105                  | 3      | 5.1434  | 2.3109    | 3                 | 5.3651  |        |
| $\beta_6 L_{III}N_I$           | 2.83672              | 9    | 4.3706  |                      |      |                      | $\gamma_2 L_I N_{II}$          | 2.0460                  | 4      | 6.060   | 1.9602    | 3                 | 6.3250  |        |
| $\beta_{2,15} L_{III}N_{IV,V}$ | 2.75053              | 8    | 4.5075  |                      |      |                      | $\gamma_3 L_I N_{III}$         | 2.0410                  | 4      | 6.074   | 1.9553    | 3                 | 6.3409  |        |
| $\beta_7 L_{III}O_I$           | 2.7288               | 3    | 4.5435  |                      |      |                      | $\gamma_4 L_I O_{II,III}$      | 1.9830                  | 4      | 6.252   | 1.8991    | 4                 | 6.528   |        |
| $\beta_{10} L_I M_{IV}$        | 2.72104              | 9    | 4.5564  |                      |      |                      | $\eta L_{II}M_I$               | 2.740                   | 3      | 4.525   | 2.6203    | 4                 | 4.7315  |        |
| $\beta_1 L_I M_V$              | 2.71352              | 9    | 4.5690  |                      |      |                      | $\beta_1 L_{II}M_{IV}$         | 2.45891                 | 5      | 5.0421  | 2.3561    | 3                 | 5.2622  |        |
| 55 Cesium                      |                      |      |         |                      |      | 56 Barium            |                                | $\gamma_5 L_{II}N_I$    | 2.2056 | 4       | 5.621     | 2.1103            | 3       | 5.8751 |
|                                |                      |      |         |                      |      |                      |                                | $\gamma_1 L_{II}N_{IV}$ | 2.1418 | 3       | 5.7885    | 2.0487            | 4       | 6.052  |
| $\alpha_2 K L_{II}$            | 0.404835             | 4    | 30.6251 | 0.389668             | 5    | 31.8171              | $\gamma_8 L_{II}O_I$           |                         |        |         | 2.0237    | 4                 | 6.126   |        |
| $\alpha_1 K L_{III}$           | 0.400290             | 4    | 30.9728 | 0.385111             | 4    | 32.1936              | $\beta_1 L_{III}M_I$           | 3.006                   | 3      | 4.124   | 2.8917    | 4                 | 4.2875  |        |
| $\beta_1 K M_{II}$             | 0.355050             | 4    | 34.9194 | 0.341507             | 4    | 36.3040              | $\alpha_2 L_{III}M_{IV}$       | 2.67533                 | 5      | 4.63423 | 2.5706    | 3                 | 4.8230  |        |
| $\beta_1 K M_{III}$            | 0.354364             | 7    | 34.9869 | 0.340811             | 3    | 36.3782              | $\alpha_1 L_{III}M_V$          | 2.66570                 | 5      | 4.65097 | 2.5615    | 2                 | 4.8402  |        |
| $\beta_2 K N_{II,III}$         | 0.34611              | 2    | 35.822  | 0.33277              | 1    | 37.257               | $\beta_6 L_{III}N_I$           | 2.3790                  | 4      | 5.2114  | 2.2818    | 3                 | 5.4334  |        |
| $K O_{II,III}$                 |                      |      |         | 0.33127              | 2    | 37.426               | $\beta_{2,15} L_{III}N_{IV,V}$ | 2.3030                  | 3      | 5.3835  | 2.2087    | 2                 | 5.6134  |        |
| $\beta_5^{II} K M_{IV}$        |                      |      |         | 0.33835              | 2    | 36.643               | $\beta_7 L_{III}O_I$           | 2.275                   | 3      | 5.450   | 2.1701    | 2                 | 5.7132  |        |
| $\beta_5^I K M_V$              |                      |      |         | 0.33814              | 2    | 36.666               | $\beta_{10} L_I M_{IV}$        | 2.290                   | 3      | 5.415   | 2.1958    | 5                 | 5.646   |        |
| $\beta_4 K N_{IV,V}$           |                      |      |         | 0.33229              | 2    | 37.311               | $\beta_3 L_I M_V$              | 2.282                   | 3      | 5.434   | 2.1885    | 3                 | 5.6650  |        |
| $\beta_1 L_I M_{II}$           | 2.6666               | 2    | 4.6494  | 2.5553               | 2    | 4.8519               | $\gamma M_{III}N_{IV,V}$       | 12.08                   | 4      | 1.027   | 11.53     | 1                 | 1.0749  |        |
| $\beta_1 L_I M_{III}$          | 2.6285               | 2    | 4.7167  | 2.5164               | 2    | 4.9269               | $\beta M_{IV}N_{VI}$           | 14.51                   | 5      | 0.854   | 13.75     | 4                 | 0.902   |        |
| $\gamma_2 L_I N_{II}$          | 2.2371               | 2    | 5.5420  | 2.1387               | 2    | 5.7969               | $\zeta M_V N_{III}$            | 19.44                   | 5      | 0.638   | 18.35     | 4                 | 0.676   |        |
| $\gamma_1 L_I N_{III}$         | 2.2328               | 2    | 5.5527  | 2.1342               | 2    | 5.8092               | $\alpha M_V N_{VI,VII}$        | 14.88                   | 5      | 0.833   | 14.04     | 2                 | 0.883   |        |