**Tables**

*Table 2. 1. The relationship between the Siegbahn and IUPAC notation for K X-ray transitions [17].*

|  |  |
| --- | --- |
| IUPAC | Siegbahn |
| K-L3  K-L2  K-M3  K-M2  K-M4,5    K-N2,3  K-N4,5  K-O2,3  K-P2,3 | Kα1  Kα2  Kβ1  Kβ3  Kβ5  Kβ2  Kβ4  Kβ2,3  Kβ2,3 |

*Table 2. 2. Shows the discrepancy in the relative intensities of L-X-ray transitions [18].*

|  |
| --- |
| Line |
| Relative Intensity 100 10 50-100 10-20 5-10 3-6 |

*Table 4.1. Incident beam energies, ions and ion charges*

|  |  |
| --- | --- |
| Carbon ions |  |
| E (MeV) | Charges |
| 12 | +3 |
| 8,6 and 4 | +2 |
| Chlorine ions |  |
| 35 | +7 |
| 28 | +6 |
| 21 | +5 |
| 14 and 7 | +3 |

*Table 4. 2. values of all the X-ray line intensities of all the target.*

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| X-ray Lines | Energy (keV) |  |  | (b) | σ (b) | solid angle |  |  | ε (p) |
| Bi\_L-alpha | 10.837 | 2707.02 | 40908.5 | 11.350 | 2.289 | 0.04617 | 3.47 10-22 | 2.88 1021 | **6.1618 10-4** |
| Bi\_L-beta | 13.021 | 2487.36 | 40908.5 | 3.324 | 2.289 | 0.04617 | 3.47 10-22 | 2.88 1021 | **1.9334 10-3** |
| Bi-L gamma | 15.245 | 949.72 | 40908.5 | 0.721 | 2.289 | 0.04617 | 3.47 10-22 | 2.88 1021 | **3.4028 10-3** |
| Gd\_L-alpha | 6.056 | 3476.73 | 29776 | 64.9735 | 1.364 | 0.04617 | 2.61 10-22 | 3.83 1022 | **1.1308 10-3** |
| Gd\_L-beta1,3,4 | 6.712 | 1600.55 | 29776 | 26.836 | 1.364 | 0.04617 | 2.61 10-22 | 3.83 1022 | **1.2604 10-3** |
| Gd\_beta 2,15 | 7.102 | 1407.73 | 29776 | 26.836 | 1.364 | 0.04617 | 2.61 10-22 | 3.83 1022 | **1.1085 10-3** |
| Gd\_L-gamma | 7.784 | 841.32 | 29776 | 4.951 | 1.364 | 0.04617 | 2.61 10-22 | 3.83 1022 | **3.5908 10-3** |
| Y\_L-alpha | 1.923 | 19204.3 | 14586.5 | 720.438 | 0.508 | 0.04617 | 1.48 10-22 | 6.77 1021 | **4.2920 10-5** |
| Y\_K-alpha | 14.956 | 1945.7 | 14586.5 | 2.40E+00 | 0.508 | 0.04617 | 1.48 10-22 | 6.77 1021 | **1.3073 10-3** |
| Y\_K-beta | 16.735 | 301 | 14586.5 | 3.62E-01 | 0.508 | 0.04617 | 1.48 10-22 | 6.77 1021 | **1.3396 10-3** |

*Table 4. 3. An illustration of how the detector efficiency correction factor was calculated.*

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Incident Energy (MeV) | X-ray Line |  |  |  | Measured Nx | Corrected Nx |
|  |  |  |  |  |  |  |
| 4 |  | 6.161 10-4 | 7.626 10-4 | 8.079 10-1 | 699.21 | 5.6494 102 |

*Table 4. 4. The total stopping power and its inverse were calculated using SRIM.*

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Ei (MeV) | Elect SP | Nucl SP | Total (S) | 1/S |
| 4 | 1.65 | 5.47 10-3 | 1.65 | 6.04 10-1 |
| 3.75 | 1.63 | 5.75 10-3 | 1.64 | 6.11 10-1 |
|  |  |  |  |  |

*Table 4.6. A table showing the values*

|  |  |  |  |
| --- | --- | --- | --- |
| E | Ei2 | g(E) | Y(E) |
| 4 | 16 | 2.6388 | -0.1 |
| 3.9 | 15.21 | 2.578232 | -0.03943 |
| 3.8 | 14.44 | 2.517386 | 0.021414 |
| 3.7 | 13.69 | 2.456264 | 0.082537 |
| 3.6 | 12.96 | 2.394864 | 0.143936 |
| 3.5 | 12.25 | 2.333188 | 0.205613 |

*Table 4. 7. A table showing E (MeV) and ECPSSR values*

|  |  |
| --- | --- |
| E(MeV) | ECPSSR |
| 4.5 | 1.5 |
| 5 | 2.5 |
| 5.5 | 4.5 |
| 6 | 6.5 |

*Table 5.1. Line intensity ratio of 209Bi, 158Gd, 119Sn and 91Zr due to carbon ions.*

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| E  (MeV) | Bi | Gd | Sn | Zr |
| 6 | 4 | 2.2 | 0.13 | 25.4 |
| 8 | 3.9 | 2.3 | 0.11 | 24.7 |
| 10 | 5.3 | 2 | 0.11 | 23.9 |
| 12 | 4.5 | 2.6 | 0.12 | 21.8 |
| Theoretical 2 MeV H+ (This work) | 4.8 | 2 | 0.13 | 23 |
| Theoretical 2 MeV H+ (Scofield) | 4.6 | 5 | 0.15 | 23.7 |

*Table 5.2. Line intensity ratio of 158Gd, 119Sn and 91Zr due to chlorine projectiles.*

|  |  |  |  |
| --- | --- | --- | --- |
| E  (MeV) | Gd | Sn | Zr |
| 7 |  | 0.07 | 23.6 |
| 14 | 3.2 | 0.07 | 28.3 |
| 21 | 2.8 | 0.14 | 24.9 |
| 28 | 3.3 | 0.09 | 25.5 |
| 35 | 3 | 0.12 | 26.5 |
| Theoretical 2 MeV H+ ( This work) | 2 | 0.14 | 23.9 |
| Theoretical 2 MeV H+ (Scofield) | 5 | 0.15 | 23.7 |

*Table 5.3. Evaluation of energy shift in Bismuth (209Bi)*

|  |  |  |  |
| --- | --- | --- | --- |
| E (MeV) | L\_X-ray lines components  Bi Energy shifts (eV) | | |
|  | ( |  |  |
| 4 |  | 270 | 510 |
| 6 | 80 | 330 | 480 |
| 8 |  | 320 | 470 |
| 10 | 60 | 390 | 610 |
| 12 | 10 | 390 | 460 |
|  |  |  |  |

*Table 5.4. Evaluation of energy shift in Gadolinium (158Gd)*

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| E (MeV) | L\_X-ray lines components  Gd Energy shifts (eV) | | |  |
|  |  |  |  | ( |
| 4 | 20 | 220 | 160 | 160 |
| 6 | 20 | 90 | 30 | 270 |
| 8 | 40 | 140 | 110 | 290 |
| 10 | 10 | 160 | 160 | 230 |
| 12 | 20 | 130 | 160 | 180 |
|  |  |  |  |  |

*Table 5.5. Evaluation of energy shift in Tin (119Sn)*

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| E (MeV) | L\_X-ray lines components  Sn Energy shifts (eV) | | | | |
|  | ( |  |  |  | ( |
| 4 | 20 | 0 | 20 | 160 | 140 |
| 6 | 30 | 20 | 20 | 90 | 150 |
| 8 | 30 | 20 | 20 | 120 | 100 |
| 10 | 40 | 100 | 30 | 100 | 90 |
| 12 | 70 | 100 | 30 | 110 | 80 |
|  |  |  |  |  |  |

*Table 5.6. Evaluation of energy shift in Zirconium (91Zr)*

|  |  |  |
| --- | --- | --- |
| E (MeV) L\_X-ray lines component  Zr energy shifts | | |
|  | ( |  |
| 4 | 41 | 30.7 |
| 6 | 51.1 | 40.7 |
| 8 | 40.9 | 51.4 |
| 10 | 50.9 | 50.9 |
| 12 | 30.7 | 40.9 |
|  |  |  |

*Table 5.7. Evaluation of energy shift in Gadolinium (158Gd)*

|  |  |  |  |
| --- | --- | --- | --- |
| E (MeV) | L\_X-ray lines components  Gd Energy shifts (eV) | | |
|  |  |  |  |
| 7 | 20 |  |  |
| 14 | 30 | 100 | 100 |
| 21 | 20 | 110 | 100 |
| 28 | 30 | 120 | 200 |
| 35 | 50 | 100 | 300 |
|  |  |  |  |

*Table 5.8. Evaluation of energy shift in Tin (119Sn****)***

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| E (MeV) | L\_X-ray lines components  Sn Energy shifts (eV) | | | |
|  | ( |  |  | ( |
| 7 | 134 | 41.7 | 62.6 | 62.6 |
| 14 | 104.4 | 83.5 | 83.5 | 83.5 |
| 21 | 94 | 93.9 | 83.5 | 83.5 |
| 28 | 93.9 | 73.1 | 104.4 | 104.4 |
| 35 | 208.7 | 208.7 | 198.2 | 198.2 |
|  |  |  |  |  |

*Table 5.9. Evaluation of energy shift in Zirconium (91Zr)*

|  |  |  |
| --- | --- | --- |
| E (MeV) | L\_X-ray lines components  Zr Energy shifts (eV) | |
|  | ( |  |
| 7 | 62.6 | 72.7 |  | |
| 14 | 104.3 | 83.5 |  | |
| 21 | 125.2 | 125.2 |  | |
| 28 | 114.8 | 125.2 |
| 35 | 146.1 | 125.2 |
|  |  |  |  |  | |  |

*Table 5.10. Summary of atomic parameters MI correction Bismuth (209Bi), Gadolinium (158Gd), Yttrium (89Y) due to carbon ions with the 2 MeV proton values for comparison: fluorescence yield and the Coster-Kronig transition.*

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Bi | | | | | | | |
| Energy (MeV) |  |  |  |  |  |  |  |
| 2 | 0.132 | 0.411 | 0.353 | 0.06 | 0.62 | 0.117 | 3.80E-03 |
| 4 | 0.261 | 0.617 | 0.558 | 0.011 | 0.115 | 0.0218 | 0.000708 |
| 6 | 0.223 | 0.569 | 0.508 | 0.0176 | 0.174 | 0.0327 | 0.001064 |
| 8 | 0.204 | 0.540 | 0.478 | 0.022 | 0.220 | 0.0414 | 0.00135 |
| 10 | 0.191 | 0.520 | 0.459 | 0.0261 | 0.256 | 0.0484 | 0.00157 |
| 12 | 0.183 | 0.506 | 0.445 | 0.0292 | 0.287 | 0.0541 | 0.00176 |
| Gd | | | | | | | |
| 2 | 0.102 | 0.175 | 0.165 | 0.19 | 0.279 | 0.15 | 0.00096 |
| 4 | 0.210 | 0.332 | 0.320 | 0.0345 | 0.0507 | 0.0272 | 0.000175 |
| 6 | 0.178 | 0.288 | 0.277 | 0.0522 | 0.0766 | 0.0412 | 0.000264 |
| 8 | 0.161 | 0.264 | 0.253 | 0.0663 | 0.0974 | 0.0523 | 0.000335 |
| 10 | 0.151 | 0.249 | 0.239 | 0.0776 | 0.114 | 0.0613 | 0.000392 |
| 12 | 0.144 | 0.239 | 0.229 | 0.0869 | 0.128 | 0.0687 | 0.000439 |
| Y | | | | | | | |
| 2 | 0.005834 | 0.0276 | 0.0279 | 0.0811 | 0.52 | 0.094 | 5.03E-05 |
| 4 | 0.0134 | 0.0638 | 0.0644 | 0.0141 | 0.0902 | 0.0163 | 8.71E-06 |
| 6 | 0.0113 | 0.0522 | 0.0528 | 0.0215 | 0.138 | 0.0250 | 1.33E-05 |
| 8 | 0.00998 | 0.0465 | 0.0470 | 0.0275 | 0.176 | 0.0319 | 1.7E-05 |
| 10 | 0.00921 | 0.0430 | 0.0435 | 0.0323 | 0.207 | 0.0375 | 2E-05 |
| 12 | 0.00869 | 0.0407 | 0.0411 | 0.0363 | 0.232 | 0.0421 | 2.25E-05 |

*Table 5.11. Summary of atomic parameters MI correction in Gadolinium (158Gd) due to Chlorine ions with the 2 MeV proton values for comparison: fluorescence yield and the Coster-Kronig transition.*

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Gd | | | | | | | |
| Energy (MeV) |  |  |  |  |  |  |  |
| 2 | 0.102 | 0.175 | 0.167 | 0.19 | 0.279 | 0.15 | 9.6E-04 |
| 7 | 0.469 | 0.622 | 0.609 | 0.00315 | 0.00462 | 0.00248 | 1.59E-05 |
| 14 | 0.255 | 0.390 | 0.376 | 0.0210 | 0.0308 | 0.0166 | 0.000106 |
| 21 | 0.200 | 0.319 | 0.307 | 0.0388 | 0.0570 | 0.0306 | 0.000196 |
| 28 | 0.176 | 0.285 | 0.274 | 0.0536 | 0.0788 | 0.0423 | 0.000271 |
| 35 | 0.162 | 0.265 | 0.254 | 0.0658 | 0.0966 | 0.0519 | 0.000332 |

*Table 5.12. Experimental (σexpt) X-ray production cross sections in 209Bi due to 4 MeV-12 MeV C ions together with calculated values of ECPSSR, ECPSSR + EC and ECPSSR + UA models with and without MI correction*.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| ENERGY (MeV) | σexpt (b) | ECPSSR (b) | ECPSSR (b) (MI) | ECPSSR+EC (b) | ECPSSR+EC (b) (MI) | ECPSSR+UA (b) | ECPSSR+UA (b) (MI) |
| 4 | 0.32 ± 0.05 | 1.06 | 1.45 | 1.11 | 1.50 | 1.09 | 1.45 |
| 6 | 3.7 ± 0.6 | 6.23 | 7.71 | 6.58 | 8.06 | 6.44 | 8.29 |
| 8 | 10.4 ± 1.5 | 18.1 | 21.7 | 19.3 | 22.8 | 18.8 | 23.7 |
| 10 | 18.3 ± 2.7 | 38.3 | 45.2 | 41.0 | 47.9 | 39.7 | 48.9 |
| 12 | 30.3 ± 4.5 | 67.3 | 79.1 | 72.6 | 84.4 | 69.7 | 84.5 |

*Table 5.13. Experimental (σexpt) X-ray production cross sections in 158Gd due to 6 MeV-12 MeV C ions together with calculated values of ECPSSR, ECPSSR + EC and ECPSSR + UA models with and without MI corrections.*

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| E (Me) | | σexpt (b) | | ECPSSR (b) | | ECPSSR (b) (MI) | | ECPSSR+EC (b) | | ECPSSR+EC (b) (MI) | | ECPSSR+UA (b) | | ECPSSR+UA (b) (MI) | |
| 6 | 99±15 | | 50 | | 79.5 | | 92 | | 106 | | 65 | | 104 | |
| 8 | 205±30 | | 129 | | 193 | | 238 | | 275 | | 155 | | 232 | |
| 10 | 328±50 | | 260 | | 368 | | 479 | | 558 | | 287 | | 401 | |
| 12 | 388±60 | | 444 | | 608 | | 601 | | 741 | | 467 | | 639 | |

*Table 5.14. Experimental (σexpt) L-shell X-ray production cross sections in 89Y due to 4 MeV-12 MeV C ions together with calculated values of the ECPSSR model with and without MI corrections.*

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| E (Me) | σexpt (kb) | ECPSSR (b) | ECPSSR (b) (MI) | ECPSSR+EC (b) | ECPSSR+EC (b) (MI) | ECPSSR+UA (b) | ECPSSR+UA (b) (MI) |
| 4 | 0.55±0.08 | 0.66 | 1.48 | 56.6 | 57.5 | 0.667 | 1.48 |
| 6 | 1.8±0.3 | 2.40 | 4.41 | 225 | 227 | 2.4 | 4.41 |
| 8 | 3.4±0.5 | 5.39 | 8.77 | 462 | 465 | 5.39 | 8.77 |
| 10 | 6.1±0.9 | 9.41 | 14.2 | 700 | 705 | 9.41 | 14.2 |
| 12 | 9.2±1.4 | 14.08 | 20.1 | 903 | 909 | 14.08 | 20.1 |

*Table 5.15. Experimental (σexpt) L-shell X-ray production cross sections in 158Gd due to 7MeV-35 MeV Cl ions together with calculated values of the ECPSSR model with and without MI*

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| E (M) | σexpt (b) | ECPSSR (b) | ECPSSR (b) (MI) | ECPSSR+EC (b) | ECPSSR+EC (b) (MI) | ECPSSR+UA (b) | ECPSSR+UA (b) (MI) |
| 14 | 98.5±10 | 13.6 | 25.9 | 2590 | 2597 | 17.5 | 34.8 |
| 21 | 1677.8±170 | 73.3 | 124 | 27149 | 27179 | 87.6 | 150 |
| 28 | 4666.9±470 | 233 | 368 | 109966 | 110072 | 246 | 389 |
| 35 | 5440.2±547 | 562 | 841 | 275766 | 276011 | 562 | 841 |