# 5. ELECTRONIC STRUCTURE OF THE ELEMENTS

**Table 5.1.** Reviewed 1999 by W.C. Martin (NIST). The electronic configurations and the ionization energies (except for a few newer values, marked with an *) are taken from "Atomic Spectroscopy," W.C. Martin and W.L. Wiese, in *Atomic, Molecular, and Optical Physics Reference Book*, G.W.F. Drake, ed., Amer. Inst. Phys., 1995. The electron configuration for, say, iron indicates an argon electronic core (see argon) plus six $3d$ electrons and two $4s$ electrons. The ionization energy is the least energy necessary to remove to infinity one electron from an atom of the element.

| | Element | | Electron configuration ($3d^5$ = five $3d$ electrons, *etc.*) | | | | | | Ground state $^{2S+1}L_J$ | Ionization energy (eV) |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | H | Hydrogen | $1s$ | | | | | | $^2S_{1/2}$ | 13.5984 |
| 2 | He | Helium | $1s^2$ | | | | | | $^1S_0$ | 24.5874 |
| 3 | Li | Lithium | (He) $2s$ | | | | | | $^2S_{1/2}$ | 5.3917 |
| 4 | Be | Beryllium | (He) $2s^2$ | | | | | | $^1S_0$ | 9.3227 |
| 5 | B | Boron | (He) $2s^2$ | $2p$ | | | | | $^2P_{1/2}$ | 8.2980 |
| 6 | C | Carbon | (He) $2s^2$ | $2p^2$ | | | | | $^3P_0$ | 11.2603 |
| 7 | N | Nitrogen | (He) $2s^2$ | $2p^3$ | | | | | $^4S_{3/2}$ | 14.5341 |
| 8 | O | Oxygen | (He) $2s^2$ | $2p^4$ | | | | | $^3P_2$ | 13.6181 |
| 9 | F | Fluorine | (He) $2s^2$ | $2p^5$ | | | | | $^2P_{3/2}$ | 17.4228 |
| 10 | Ne | Neon | (He) $2s^2$ | $2p^6$ | | | | | $^1S_0$ | 21.5646 |
| 11 | Na | Sodium | (Ne) $3s$ | | | | | | $^2S_{1/2}$ | 5.1391 |
| 12 | Mg | Magnesium | (Ne) $3s^2$ | | | | | | $^1S_0$ | 7.6462 |
| 13 | Al | Aluminum | (Ne) $3s^2$ | $3p$ | | | | | $^2P_{1/2}$ | 5.9858 |
| 14 | Si | Silicon | (Ne) $3s^2$ | $3p^2$ | | | | | $^3P_0$ | 8.1517 |
| 15 | P | Phosphorus | (Ne) $3s^2$ | $3p^3$ | | | | | $^4S_{3/2}$ | 10.4867 |
| 16 | S | Sulfur | (Ne) $3s^2$ | $3p^4$ | | | | | $^3P_2$ | 10.3600 |
| 17 | Cl | Chlorine | (Ne) $3s^2$ | $3p^5$ | | | | | $^2P_{3/2}$ | 12.9676 |
| 18 | Ar | Argon | (Ne) $3s^2$ | $3p^6$ | | | | | $^1S_0$ | 15.7596 |
| 19 | K | Potassium | (Ar) | $4s$ | | | | | $^2S_{1/2}$ | 4.3407 |
| 20 | Ca | Calcium | (Ar) | $4s^2$ | | | | | $^1S_0$ | 6.1132 |
| 21 | Sc | Scandium | (Ar) $3d$ | $4s^2$ | Transition elements | | | | $^2D_{3/2}$ | 6.5615 |
| 22 | Ti | Titanium | (Ar) $3d^2$ | $4s^2$ | | | | | $^3F_2$ | 6.8281 |
| 23 | V | Vanadium | (Ar) $3d^3$ | $4s^2$ | | | | | $^4F_{3/2}$ | 6.7463 |
| 24 | Cr | Chromium | (Ar) $3d^5$ | $4s$ | | | | | $^7S_3$ | 6.7665 |
| 25 | Mn | Manganese | (Ar) $3d^5$ | $4s^2$ | | | | | $^6S_{5/2}$ | 7.4340 |
| 26 | Fe | Iron | (Ar) $3d^6$ | $4s^2$ | | | | | $^5D_4$ | 7.9024 |
| 27 | Co | Cobalt | (Ar) $3d^7$ | $4s^2$ | | | | | $^4F_{9/2}$ | 7.8810 |
| 28 | Ni | Nickel | (Ar) $3d^8$ | $4s^2$ | | | | | $^3F_4$ | 7.6398 |
| 29 | Cu | Copper | (Ar) $3d^{10}$ | $4s$ | | | | | $^2S_{1/2}$ | 7.7264 |
| 30 | Zn | Zinc | (Ar) $3d^{10}$ | $4s^2$ | | | | | $^1S_0$ | 9.3942 |
| 31 | Ga | Gallium | (Ar) $3d^{10}$ | $4s^2$ | $4p$ | | | | $^2P_{1/2}$ | 5.9993 |
| 32 | Ge | Germanium | (Ar) $3d^{10}$ | $4s^2$ | $4p^2$ | | | | $^3P_0$ | 7.8994 |
| 33 | As | Arsenic | (Ar) $3d^{10}$ | $4s^2$ | $4p^3$ | | | | $^4S_{3/2}$ | 9.7886 |
| 34 | Se | Selenium | (Ar) $3d^{10}$ | $4s^2$ | $4p^4$ | | | | $^3P_2$ | 9.7524 |
| 35 | Br | Bromine | (Ar) $3d^{10}$ | $4s^2$ | $4p^5$ | | | | $^2P_{3/2}$ | 11.8138 |
| 36 | Kr | Krypton | (Ar) $3d^{10}$ | $4s^2$ | $4p^6$ | | | | $^1S_0$ | 13.9996 |
| 37 | Rb | Rubidium | (Kr) | $5s$ | | | | | $^2S_{1/2}$ | 4.1771 |
| 38 | Sr | Strontium | (Kr) | $5s^2$ | | | | | $^1S_0$ | 5.6949 |
| 39 | Y | Yttrium | (Kr) $4d$ | $5s^2$ | Transition elements | | | | $^2D_{3/2}$ | 6.2171 |
| 40 | Zr | Zirconium | (Kr) $4d^2$ | $5s^2$ | | | | | $^3F_2$ | 6.6339 |
| 41 | Nb | Niobium | (Kr) $4d^4$ | $5s$ | | | | | $^6D_{1/2}$ | 6.7589 |
| 42 | Mo | Molybdenum | (Kr) $4d^5$ | $5s$ | | | | | $^7S_3$ | 7.0924 |
| 43 | Tc | Technetium | (Kr) $4d^5$ | $5s^2$ | | | | | $^6S_{5/2}$ | 7.28 |
| 44 | Ru | Ruthenium | (Kr) $4d^7$ | $5s$ | | | | | $^5F_5$ | 7.3605 |
| 45 | Rh | Rhodium | (Kr) $4d^8$ | $5s$ | | | | | $^4F_{9/2}$ | 7.4589 |
| 46 | Pd | Palladium | (Kr) $4d^{10}$ | | | | | | $^1S_0$ | 8.3369 |
| 47 | Ag | Silver | (Kr) $4d^{10}$ | $5s$ | | | | | $^2S_{1/2}$ | 7.5762* |
| 48 | Cd | Cadmium | (Kr) $4d^{10}$ | $5s^2$ | | | | | $^1S_0$ | 8.9938 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 49 | In | Indium | (Kr) $4d^{10}5s^2$ | $5p$ | | | | | $^2P_{1/2}$ | 5.7864 |
| 50 | Sn | Tin | (Kr) $4d^{10}5s^2$ | $5p^2$ | | | | | $^3P_0$ | 7.3439 |
| 51 | Sb | Antimony | (Kr) $4d^{10}5s^2$ | $5p^3$ | | | | | $^4S_{3/2}$ | 8.6084 |
| 52 | Te | Tellurium | (Kr) $4d^{10}5s^2$ | $5p^4$ | | | | | $^3P_2$ | 9.0096 |
| 53 | I | Iodine | (Kr) $4d^{10}5s^2$ | $5p^5$ | | | | | $^2P_{3/2}$ | 10.4513 |
| 54 | Xe | Xenon | (Kr) $4d^{10}5s^2$ | $5p^6$ | | | | | $^1S_0$ | 12.1298 |
| 55 | Cs | Cesium | (Xe) | $6s$ | | | | | $^2S_{1/2}$ | 3.8939 |
| 56 | Ba | Barium | (Xe) | $6s^2$ | | | | | $^1S_0$ | 5.2117 |
| 57 | La | Lanthanum | (Xe) $5d$ | $6s^2$ | | | | | $^2D_{3/2}$ | 5.5770 |
| 58 | Ce | Cerium | (Xe) $4f$ $5d$ | $6s^2$ | | | | | $^1G_4$ | 5.5387 |
| 59 | Pr | Praseodymium | (Xe) $4f^3$ | $6s^2$ | | L | | | $^4I_{9/2}$ | 5.464 |
| 60 | Nd | Neodymium | (Xe) $4f^4$ | $6s^2$ | | a | | | $^5I_4$ | 5.5250 |
| 61 | Pm | Promethium | (Xe) $4f^5$ | $6s^2$ | | n | | | $^6H_{5/2}$ | 5.58 |
| 62 | Sm | Samarium | (Xe) $4f^6$ | $6s^2$ | | t | | | $^7F_0$ | 5.6436 |
| 63 | Eu | Europium | (Xe) $4f^7$ | $6s^2$ | | h | | | $^8S_{7/2}$ | 5.6704 |
| 64 | Gd | Gadolinium | (Xe) $4f^7$ $5d$ | $6s^2$ | | a | | | $^9D_2$ | 6.1498* |
| 65 | Tb | Terbium | (Xe) $4f^9$ | $6s^2$ | | n | | | $^6H_{15/2}$ | 5.8638 |
| 66 | Dy | Dysprosium | (Xe) $4f^{10}$ | $6s^2$ | | i | | | $^5I_8$ | 5.9389 |
| 67 | Ho | Holmium | (Xe) $4f^{11}$ | $6s^2$ | | d | | | $^4I_{15/2}$ | 6.0215 |
| 68 | Er | Erbium | (Xe) $4f^{12}$ | $6s^2$ | | e | | | $^3H_6$ | 6.1077 |
| 69 | Tm | Thulium | (Xe) $4f^{13}$ | $6s^2$ | | s | | | $^2F_{7/2}$ | 6.1843 |
| 70 | Yb | Ytterbium | (Xe) $4f^{14}$ | $6s^2$ | | | | | $^1S_0$ | 6.2542 |
| 71 | Lu | Lutetium | (Xe) $4f^{14}5d$ | $6s^2$ | | | | | $^2D_{3/2}$ | 5.4259 |
| 72 | Hf | Hafnium | (Xe) $4f^{14}5d^2$ | $6s^2$ | | T | | | $^3F_2$ | 6.8251 |
| 73 | Ta | Tantalum | (Xe) $4f^{14}5d^3$ | $6s^2$ | | r | e | | $^4F_{3/2}$ | 7.5496 |
| 74 | W | Tungsten | (Xe) $4f^{14}5d^4$ | $6s^2$ | | a | l | | $^5D_0$ | 7.8640 |
| 75 | Re | Rhenium | (Xe) $4f^{14}5d^5$ | $6s^2$ | | n | e | | $^6S_{5/2}$ | 7.8335 |
| 76 | Os | Osmium | (Xe) $4f^{14}5d^6$ | $6s^2$ | | s | m | | $^5D_4$ | 8.4382* |
| 77 | Ir | Iridium | (Xe) $4f^{14}5d^7$ | $6s^2$ | | i | e | | $^4F_{9/2}$ | 8.9670* |
| 78 | Pt | Platinum | (Xe) $4f^{14}5d^9$ | $6s$ | | t | n | | $^3D_3$ | 8.9587 |
| 79 | Au | Gold | (Xe) $4f^{14}5d^{10}6s$ | | | i | t | | $2S_{1/2}$ | 9.2255 |
| 80 | Hg | Mercury | (Xe) $4f^{14}5d^{10}6s^2$ | | | o | s | | $^1S_0$ | 10.4375 |
| 81 | Tl | Thallium | (Xe) $4f^{14}5d^{10}6s^2$ | $6p$ | | n | | | $^2P_{1/2}$ | 6.1082 |
| 82 | Pb | Lead | (Xe) $4f^{14}5d^{10}6s^2$ | $6p^2$ | | | | | $^3P_0$ | 7.4167 |
| 83 | Bi | Bismuth | (Xe) $4f^{14}5d^{10}6s^2$ | $6p^3$ | | | | | $^4S_{3/2}$ | 7.2855* |
| 84 | Po | Polonium | (Xe) $4f^{14}5d^{10}6s^2$ | $6p^4$ | | | | | $^3P_2$ | 8.4167 |
| 85 | At | Astatine | (Xe) $4f^{14}5d^{10}6s^2$ | $6p^5$ | | | | | $^2P_{3/2}$ | |
| 86 | Rn | Radon | (Xe) $4f^{14}5d^{10}6s^2$ | $6p^6$ | | | | | $^1S_0$ | 10.7485 |
| 87 | Fr | Francium | (Rn) | $7s$ | | | | | $^2S_{1/2}$ | 4.0727 |
| 88 | Ra | Radium | (Rn) | $7s^2$ | | | | | $^1S_0$ | 5.2784 |
| 89 | Ac | Actinium | (Rn) $6d$ | $7s^2$ | | | | | $^2D_{3/2}$ | 5.17 |
| 90 | Th | Thorium | (Rn) $6d^2$ | $7s^2$ | | | | | $^3F_2$ | 6.3067 |
| 91 | Pa | Protactinium | (Rn)$5f^2$ $6d$ | $7s^2$ | | A | | | $^4K_{11/2}$ | 5.89 |
| 92 | U | Uranium | (Rn)$5f^3$ $6d$ | $7s^2$ | | c | | | $^5L_6$ | 6.1941 |
| 93 | Np | Neptunium | (Rn)$5f^4$ $6d$ | $7s^2$ | | t | | | $^6L_{11/2}$ | 6.2657 |
| 94 | Pu | Plutonium | (Rn)$5f^6$ | $7s^2$ | | i | | | $^7F_0$ | 6.0262 |
| 95 | Am | Americium | (Rn)$5f^7$ | $7s^2$ | | n | | | $^8S_{7/2}$ | 5.9738 |
| 96 | Cm | Curium | (Rn)$5f^7$ $6d$ | $7s^2$ | | i | | | $^9D_2$ | 5.9915* |
| 97 | Bk | Berkelium | (Rn)$5f^9$ | $7s^2$ | | d | | | $^6H_{15/2}$ | 6.1979* |
| 98 | Cf | Californium | (Rn)$5f^{10}$ | $7s^2$ | | e | | | $^5I_8$ | 6.2817* |
| 99 | Es | Einsteinium | (Rn)$5f^{11}$ | $7s^2$ | | s | | | $^4I_{15/2}$ | 6.42 |
| 100 | Fm | Fermium | (Rn)$5f^{12}$ | $7s^2$ | | | | | $^3H_6$ | 6.50 |
| 101 | Md | Mendelevium | (Rn)$5f^{13}$ | $7s^2$ | | | | | $^2F_{7/2}$ | 6.58 |
| 102 | No | Nobelium | (Rn)$5f^{14}$ | $7s^2$ | | | | | $^1S_0$ | 6.65 |
| 103 | Lr | Lawrencium | (Rn)$5f^{14}$ | $7s^2$ | $7p$? | | | | $^2P_{1/2}$? | |
| 104 | Rf | Rutherfordium | (Rn)$5f^{14}6d^2$ | $7s^2$? | | | | | $^3F_2$? | 6.0? |