

5. Electronic Structure of the Elements

Table 5.1. Reviewed 2011 by J.E. Sansonetti (NIST). The electronic configurations and the ionization energies are from the NIST database, “Ground Levels and Ionization Energies for the Neutral Atoms,” W.C. Martin, A. Musgrove, S. Kotochigova, and J.E. Sansonetti, http://www.nist.gov/pml/data/ion_energy.cfm. The electron configuration for, say, iron indicates an argon electronic core (see argon) plus six $3d$ electrons and two $4s$ electrons.

| | Element | Electron configuration ($3d^5 =$ five $3d$ electrons, <i>etc.</i>) | Ground state $2S+1L_J$ | 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 | 21.5645 |
| 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) $3d 4s^2$ | $^2D_{3/2}$ | 6.5615 |
| 22 | Ti Titanium | (Ar) $3d^2 4s^2$ | 3F_2 | 6.8281 |
| 23 | V Vanadium | (Ar) $3d^3 4s^2$ | $^4F_{3/2}$ | 6.7462 |
| 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 | 7.6399 |
| 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) $4d 5s^2$ | $^2D_{3/2}$ | 6.2173 |
| 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 | | | ² P _{1/2} | 5.7864 |
| 50 | Sn | Tin | (Kr)4d ¹⁰ 5s ² 5p ² | | | ³ P ₀ | 7.3439 |
| 51 | Sb | Antimony | (Kr)4d ¹⁰ 5s ² 5p ³ | | | ⁴ S _{3/2} | 8.6084 |
| 52 | Te | Tellurium | (Kr)4d ¹⁰ 5s ² 5p ⁴ | | | ³ P ₂ | 9.0096 |
| 53 | I | Iodine | (Kr)4d ¹⁰ 5s ² 5p ⁵ | | | ² P _{3/2} | 10.4513 |
| 54 | Xe | Xenon | (Kr)4d ¹⁰ 5s ² 5p ⁶ | | | ¹ S ₀ | 12.1298 |
| 55 | Cs | Cesium | (Xe) 6s | | | ² S _{1/2} | 3.8939 |
| 56 | Ba | Barium | (Xe) 6s ² | | | ¹ S ₀ | 5.2117 |
| 57 | La | Lanthanum | (Xe) 5d 6s ² | | | ² D _{3/2} | 5.5769 |
| 58 | Ce | Cerium | (Xe)4f 5d 6s ² | | | ¹ G ₄ | 5.5387 |
| 59 | Pr | Praseodymium | (Xe)4f ³ 6s ² | L | | ⁴ I _{9/2} | 5.473 |
| 60 | Nd | Neodymium | (Xe)4f ⁴ 6s ² | a | | ⁵ I ₄ | 5.5250 |
| 61 | Pm | Promethium | (Xe)4f ⁵ 6s ² | n | | ⁶ H _{5/2} | 5.582 |
| 62 | Sm | Samarium | (Xe)4f ⁶ 6s ² | t | | ⁷ F ₀ | 5.6437 |
| 63 | Eu | Europium | (Xe)4f ⁷ 6s ² | h | | ⁸ S _{7/2} | 5.6704 |
| 64 | Gd | Gadolinium | (Xe)4f ⁷ 5d 6s ² | a | | ⁹ D ₂ | 6.1498 |
| 65 | Tb | Terbium | (Xe)4f ⁹ 6s ² | n | | ⁶ H _{15/2} | 5.8638 |
| 66 | Dy | Dysprosium | (Xe)4f ¹⁰ 6s ² | i | | ⁵ I ₈ | 5.9389 |
| 67 | Ho | Holmium | (Xe)4f ¹¹ 6s ² | d | | ⁴ I _{15/2} | 6.0215 |
| 68 | Er | Erbium | (Xe)4f ¹² 6s ² | e | | ³ H ₆ | 6.1077 |
| 69 | Tm | Thulium | (Xe)4f ¹³ 6s ² | s | | ² F _{7/2} | 6.1843 |
| 70 | Yb | Ytterbium | (Xe)4f ¹⁴ 6s ² | | | ¹ S ₀ | 6.2542 |
| 71 | Lu | Lutetium | (Xe)4f ¹⁴ 5d 6s ² | | | ² D _{3/2} | 5.4259 |
| 72 | Hf | Hafnium | (Xe)4f ¹⁴ 5d ² 6s ² | T | | ³ F ₂ | 6.8251 |
| 73 | Ta | Tantalum | (Xe)4f ¹⁴ 5d ³ 6s ² | r | | ⁴ F _{3/2} | 7.5496 |
| 74 | W | Tungsten | (Xe)4f ¹⁴ 5d ⁴ 6s ² | a | | ⁵ D ₀ | 7.8640 |
| 75 | Re | Rhenium | (Xe)4f ¹⁴ 5d ⁵ 6s ² | n | | ⁶ S _{5/2} | 7.8335 |
| 76 | Os | Osmium | (Xe)4f ¹⁴ 5d ⁶ 6s ² | s | | ⁵ D ₄ | 8.4382 |
| 77 | Ir | Iridium | (Xe)4f ¹⁴ 5d ⁷ 6s ² | i | | ⁴ F _{9/2} | 8.9670 |
| 78 | Pt | Platinum | (Xe)4f ¹⁴ 5d ⁹ 6s | t | | ³ D ₃ | 8.9588 |
| 79 | Au | Gold | (Xe)4f ¹⁴ 5d ¹⁰ 6s | i | | ² S _{1/2} | 9.2255 |
| 80 | Hg | Mercury | (Xe)4f ¹⁴ 5d ¹⁰ 6s ² | o | | ¹ S ₀ | 10.4375 |
| 81 | Tl | Thallium | (Xe)4f ¹⁴ 5d ¹⁰ 6s ² 6p | n | | ² P _{1/2} | 6.1082 |
| 82 | Pb | Lead | (Xe)4f ¹⁴ 5d ¹⁰ 6s ² 6p ² | | | ³ P ₀ | 7.4167 |
| 83 | Bi | Bismuth | (Xe)4f ¹⁴ 5d ¹⁰ 6s ² 6p ³ | | | ⁴ S _{3/2} | 7.2855 |
| 84 | Po | Polonium | (Xe)4f ¹⁴ 5d ¹⁰ 6s ² 6p ⁴ | | | ³ P ₂ | 8.414 |
| 85 | At | Astatine | (Xe)4f ¹⁴ 5d ¹⁰ 6s ² 6p ⁵ | | | ² P _{3/2} | |
| 86 | Rn | Radon | (Xe)4f ¹⁴ 5d ¹⁰ 6s ² 6p ⁶ | | | ¹ S ₀ | 10.7485 |
| 87 | Fr | Francium | (Rn) 7s | | | ² S _{1/2} | 4.0727 |
| 88 | Ra | Radium | (Rn) 7s ² | | | ¹ S ₀ | 5.2784 |
| 89 | Ac | Actinium | (Rn) 6d 7s ² | | | ² D _{3/2} | 5.3807 |
| 90 | Th | Thorium | (Rn) 6d ² 7s ² | | | ³ F ₂ | 6.3067 |
| 91 | Pa | Protactinium | (Rn)5f ² 6d 7s ² | A | | ⁴ K _{11/2} * | 5.89 |
| 92 | U | Uranium | (Rn)5f ³ 6d 7s ² | c | | ⁵ L ₆ * | 6.1939 |
| 93 | Np | Neptunium | (Rn)5f ⁴ 6d 7s ² | t | | ⁶ L _{11/2} * | 6.2657 |
| 94 | Pu | Plutonium | (Rn)5f ⁶ 7s ² | i | | ⁷ F ₀ | 6.0260 |
| 95 | Am | Americium | (Rn)5f ⁷ 7s ² | n | | ⁸ S _{7/2} | 5.9738 |
| 96 | Cm | Curium | (Rn)5f ⁷ 6d 7s ² | d | | ⁹ D ₂ | 5.9914 |
| 97 | Bk | Berkelium | (Rn)5f ⁹ 7s ² | e | | ⁶ H _{15/2} | 6.1979 |
| 98 | Cf | Californium | (Rn)5f ¹⁰ 7s ² | s | | ⁵ I ₈ | 6.2817 |
| 99 | Es | Einsteinium | (Rn)5f ¹¹ 7s ² | | | ⁴ I _{15/2} | 6.3676 |
| 100 | Fm | Fermium | (Rn)5f ¹² 7s ² | | | ³ H ₆ | 6.50 |
| 101 | Md | Mendelevium | (Rn)5f ¹³ 7s ² | | | ² F _{7/2} | 6.58 |
| 102 | No | Nobelium | (Rn)5f ¹⁴ 7s ² | | | ¹ S ₀ | 6.65 |
| 103 | Lr | Lawrencium | (Rn)5f ¹⁴ 7s ² 7p? | | | ² P _{1/2} ? | 4.9? |
| 104 | Rf | Rutherfordium | (Rn)5f ¹⁴ 6d ² 7s ² ? | | | ³ F ₂ ? | 6.0? |

* The usual *LS* coupling scheme does not apply for these three elements. See the introductory note to the NIST table from which this table is taken.