# APPENDIX B

**Properties of the Elements and Certain Molecules**

| Element or molecule | Symbol | Atomic number | Atomic or molecular weight* | Nominal density, gm/cm³ | Atoms or molecules per cm³† | $\sigma_a$,‡ barns | $\sigma_s$,‡ barns | $\Sigma_a$,† cm⁻¹ | $\Sigma_s$,† cm⁻¹ |
|---|---|---|---|---|---|---|---|---|---|
| Actinium | Ac | 89 | 227 | | | 800 | | | |
| Aluminum | Al | 13 | 26.9815 | 2.699 | 0.06024 | 0.235 | 1.4 | 0.01416 | 0.08434 |
| Antimony | Sb | 51 | 121.75 | 6.62 | 0.03275 | 5.5 | 4.3 | 0.1801 | 0.1408 |
| Argon | Ar | 18 | 39.948 | Gas | | 0.63 | 1.5 | | |
| Arsenic | As | 33 | 74.9216 | 5.73 | 0.04606 | 4.5 | 6 | 0.2073 | 0.2764 |
| Barium | Ba | 56 | 137.34 | 3.5 | 0.01535 | 1.2 | 8 | 0.01842 | 0.1228 |
| Beryllium | Be | 4 | 9.0122 | 1.85 | 0.1236 | 0.0095 | 7.0 | 0.001174 | 0.8652 |
| Beryllium oxide | BeO | | 25.0116 | 2.96 | 0.07127 | 0.0095 | 6.8 | 0.0006771 | 0.4846 |
| Bismuth | Bi | 83 | 208.980 | 9.80 | 0.02824 | 0.034 | 9 | 0.0009602 | 0.2542 |
| Boron | B | 5 | 10.811 | 2.3 | 0.1281 | 759 | 4 | 97.23 | 0.5124 |
| Bromine | Br | 35 | 79.909 | 3.12 | 0.02351 | 6.7 | 6 | 0.1575 | 0.1411 |
| Cadmium | Cd | 48 | 112.40 | 8.65 | 0.04635 | 2450 | 7 | 113.6 | 0.3245 |
| Calcium | Ca | 20 | 40.08 | 1.55 | 0.02329 | 0.43 | 3.0 | 0.01002 | 0.06987 |
| Carbon (graphite)** | C | 6 | 12.01115 | 1.60 | 0.08023 | 0.0034 | 4.8 | 0.0002728 | 0.3851 |
| Cerium | Ce | 58 | 140.12 | 6.78 | 0.02914 | 0.7 | 9 | 0.02040 | 0.2623 |
| Cesium | Cs | 55 | 132.905 | 1.9 | 0.008610 | 30 | 20 | 0.2583 | 0.1722 |
| Chlorine | Cl | 17 | 35.453 | Gas | | 33 | 16 | | |
| Chromium | Cr | 24 | 51.996 | 7.19 | 0.08328 | 3.1 | 3 | 0.2582 | 0.2498 |
| Cobalt | Co | 27 | 58.9332 | 8.8 | 0.08993 | 37 | 7 | 3.327 | 0.6295 |
| Columbium (see niobium) | | | | | | | | | |
| Copper | Cu | 29 | 63.54 | 8.96 | 0.08493 | 3.8 | 7.2 | 0.3227 | 0.6115 |
| Deuterium | D | 1 | 2.01410 | Gas | | 0.0005 | | | |
| Dysprosium | Dy | 66 | 162.50 | 8.56 | 0.03172 | 940 | 100 | 29.82 | 3.172 |
| Erbium | Er | 68 | 167.26 | 9.16 | 0.03203 | 160 | 15 | 5.125 | 0.4805 |
| Europium | Eu | 63 | 151.96 | 5.22 | 0.02069 | 4300 | 8 | 88.97 | 0.1655 |
| Fluorine | F | 9 | 18.9984 | Gas | | 0.0098 | 3.9 | | |
| Gadolinium | Gd | 64 | 157.25 | 7.95 | 0.03045 | 46,000 | 4 | 1401 | 0.1218 |
| Gallium | Ga | 31 | 69.72 | 5.91 | 0.05105 | 3.0 | | 0.1532 | |
| Germanium | Ge | 32 | 72.59 | 5.36 | 0.04447 | 2.4 | 3 | 0.1067 | 0.1334 |
| Gold | Au | 79 | 196.967 | 19.32 | 0.05907 | 98.8 | 9.3 | 5.836 | 0.5494 |
| Hafnium | Hf | 72 | 178.49 | 13.36 | 0.04508 | 105 | 8 | 4.733 | 0.3606 |
| Heavy water†† | $D_2O$ | | 20.0276 | 1.105 | 0.03323 | 0.0010 | 13.6 | $3.323 \times 10^{-5}$ | 0.4519 |
| Helium | He | 2 | 4.0026 | Gas | | ≤0.050 | 0.8 | | |
| Holmium | Ho | 67 | 164.930 | 8.76 | 0.03199 | 65 | | 2.079 | |
| Hydrogen | H | 1 | 1.008665 | Gas | | 0.332 | | | |
| Illinium (see promethium | | | | | | | | | |
| Indium | In | 49 | 114.82 | 7.31 | 0.03834 | 194 | 2.2 | 7.438 | 0.08435 |
| Iodine | I | 53 | 126.9044 | 4.93 | 0.02340 | 6.4 | 3.6 | 0.1498 | 0.08242 |
| Iridium | Ir | 77 | 192.2 | 22.5 | 0.07050 | 460 | | 32.43 | |
| Iron | Fe | 26 | 55.847 | 7.87 | 0.08487 | 2.53 | 11 | 0.2147 | 0.9336 |
| Krypton | Kr | 36 | 83.80 | Gas | | 24 | 7.2 | | |
| Lanthanum | La | 57 | 138.91 | 6.19 | 0.02684 | 8.9 | 15 | 0.2389 | 0.4026 |
| Lead | Pb | 82 | 203.973 | 11.34 | 0.03348 | 0.17 | 11 | 0.005692 | 0.3683 |
| Lithium | Li | 3 | 6.939 | 0.53 | 0.04600 | 71 | 1.4 | 3.266 | 0.0644 |
| Lutetium | Lu | 71 | 174.91 | 9.74 | 0.03354 | 80 | | 2.683 | |
| Magnesium | Mg | 12 | 24.312 | 1.74 | 0.04310 | 0.063 | 4 | 0.002715 | 0.1724 |
| Manganese | Mn | 25 | 54.9380 | 7.43 | 0.08145 | 13.3 | 2.3 | 1.083 | 0.1873 |
| Mercury | Hg | 80 | 200.59 | 13.55 | 0.04068 | 360 | 20 | 14.64 | 0.8136 |
| Molybdenum | Mo | 42 | 95.94 | 10.2 | 0.06403 | 2.6 | 7 | 0.1665 | 0.4482 |
| Neodymium | Nd | 60 | 144.24 | 6.98 | 0.02914 | 50 | 16 | 1.457 | 0.4662 |
| Neon | Ne | 10 | 20.183 | Gas | | 0.032 | 2.4 | | |
| Nickel | Ni | 28 | 58.71 | 8.90 | 0.09130 | 4.6 | 17.5 | 0.4200 | 1.597 |
| Niobium | Nb | 41 | 92.906 | 8.57 | 0.05555 | 1.1 | 5 | 0.06111 | 0.2778 |
| Nitrogen | N | 7 | 14.0067 | Gas | | 1.85 | 10 | | |

| Element or molecule | Symbol | Atomic number | Atomic or molecular weight* | Nominal density, gm/cm³ | Atoms or molecules per cm³† | $\sigma_a$‡ barns | $\sigma_s$‡ barns | $\Sigma_a$† cm⁻¹ | $\Sigma_s$† cm⁻¹ |
|---|---|---|---|---|---|---|---|---|---|
| Osmium | Os | 76 | 190.2 | 22.5 | 0.07124 | 15 | 11 | 1.069 | 0.7836 |
| Oxygen | O | 8 | 15.9994 | Gas | | <0.0002 | 4.2 | | |
| Palladium | Pd | 46 | 106.4 | 12.0 | 0.06792 | 8 | 3.6 | 0.5434 | 0.2445 |
| Phosphorus (yellow) | P | 15 | 30.9738 | 1.82 | 0.03539 | 0.19 | 5 | 0.006724 | 0.1770 |
| Platinum | Pt | 78 | 195.09 | 21.45 | 0.06622 | 10 | 10 | 0.6622 | 0.6622 |
| Plutonium | Pu | 94 | 239 | 19.6 | 0.04939 | $\sigma_a$ = 1015<br>$\sigma_f$ = 741 | 9.6 | 49.88<br>36.55 | 0.4741 |
| Polonium | Po | 84 | 210 | 9.51 | 0.02727 | | | | |
| Potassium | K | 19 | 39.102 | 0.86 | 0.01325 | 2.1 | 1.5 | 0.02783 | 0.01988 |
| Praseodymium | Pr | 59 | 140.907 | 6.78 | 0.02898 | 12 | 4 | 0.1965 | 0.1159 |
| Promethium | Pm | 61 | | | | | | | |
| Protactinium | Pa | 91 | 231 | | | 210 | | | |
| Radium | Ra | 88 | 226 | 5.0 | 0.01332 | 20 | | 0.2664 | |
| Rhenium | Re | 75 | 186.2 | 20 | 0.06596 | 85 | 14 | 5.607 | 0.9234 |
| Rhodium | Rh | 45 | 102.905 | 12.41 | 0.07263 | 155 | 5 | 11.26 | 0.3632 |
| Rubidium | Rb | 37 | 85.47 | 1.53 | 0.01078 | 0.73 | 12 | 0.007869 | 0.1294 |
| Ruthenium | Ru | 44 | 101.07 | 12.2 | 0.07270 | 2.5 | 6 | 0.1818 | 0.4362 |
| Samarium | Sm | 62 | 150.35 | 6.93 | 0.02776 | 5800 | 5 | 161.0 | 0.1388 |
| Scandium | Sc | 21 | 44.956 | 2.5 | 0.03349 | 23 | 24 | 0.7703 | 0.8038 |
| Selenium | Se | 34 | 78.96 | 4.81 | 0,03669 | 12 | 11 | 0.4403 | 0.4036 |
| Silicon | Si | 14 | 28.086 | 2.33 | 0.04996 | 0.16 | 1.7 | 0.1164 | 0.08493 |
| Silver | Ag | 47 | 107.870 | 10.49 | 0.05857 | 63 | 6 | 3.690 | 0.3514 |
| Sodium | Na | 11 | 22.9898 | 0.97 | 0.02541 | 0.53 | 4 | 0.01347 | 0.1016 |
| Strontium | Sr | 38 | 87.62 | 2.6 | 0.01787 | 1.3 | 10 | 0.02323 | 0.1787 |
| Sulfur (yellow) | S | 16 | 32.064 | 2.07 | 0.03888 | 0.52 | 1.1 | 0.2022 | 0.04277 |
| Tantalum | Ta | 73 | 180.948 | 16.6 | 0.05525 | 21 | 5 | 1.160 | 0.2763 |
| Technetium | Tc | 43 | 99 | | | 22 | | | |
| Tellurium | Te | 52 | 127.60 | 6.24 | 0.02945 | 4.7 | 5 | 0.1384 | 0.1473 |
| Terbium | Tb | 65 | 158.924 | 8.33 | 0.03157 | 46 | | 1.452 | |
| Thallium | Tl | 81 | 204.37 | 11.85 | 0.03492 | 3.3 | 14 | 0.1152 | 0.4889 |
| Thorium | Th | 90 | 232.038 | 11.71 | 0.03039 | 7.4 | 12.6 | 0.2249 | 0.3829 |
| Thulium | Tm | 69 | 168.934 | 9.35 | 0.03314 | 125 | 7 | 4.143 | 0.2320 |
| Tin | Sn | 50 | 118.69 | 7.298 | 0.03703 | 0.63 | 4 | 0.02333 | 0.1481 |
| Titanium | Ti | 22 | 47.90 | 4.51 | 0.05670 | 6.1 | 4 | 0.3459 | 0.2268 |
| Tungsten | W | 74 | 183.85 | 19.2 | 0.06289 | 19 | 5 | 1.195 | 0.3145 |
| Uranium | U | 92 | 238.03 | 19.1 | 0.04833 | $\sigma_a$ = 7.6<br>$\sigma_f$ = 4.2 | 8.3 | 0.3673<br>0.2030 | 0.4011 |
| Vanadium | V | 23 | 50.942 | 6.1 | 0.07212 | 4.9 | 5 | 0.3534 | 0.3606 |
| Water | $H_2O$ | | 18.0167 | 1.0 | 0.03343 | 0.664 | 103 | 0.02220 | 3.443 |
| Xenon | Xe | 54 | 131.30 | Gas | | 24 | 4.3 | | |
| Ytterbium | Yb | 70 | 173.04 | 7.01 | 0.02440 | 37 | 12 | 0.9208 | 0.2928 |
| Yttrium | Y | 39 | 88.905 | 5.51 | 0.03733 | 1.3 | 3 | 0.04853 | 0.1120 |
| Zinc | Zn | 30 | 65.37 | 7.133 | 0.06572 | 1.10 | 3.6 | 0.07229 | 0.2366 |
| Zirconium | Zr | 40 | 91.22 | 6.5 | 0.04291 | 0.18 | 8 | 0.007724 | 0.3433 |

* Based on $C^{12}$ = 12.00000 amu.

† Four-digit accuracy for computational purposes only; last digit(s) usually is not meaningful.

‡ Cross sections at 0.0253 eV or 2200 m/sec. The scattering cross sections, except for those of $H_2O$ and $D_2O$, are measured values in a thermal neutron spectrum and are assumed to be 0.0253 eV values because $\sigma_s$ is usually constant at thermal energies. The errors in $\sigma_s$ tend to be large, and the tabulated values of $\sigma_s$ should be used with caution. (From BNL-325, 2nd ed., 1958 plus supplements 1 and 2, 1960, 1964, and 1965.)

** The value of $\sigma_a$ given in the table is for pure graphite. Commercial reactor-grade graphite contains varying amounts of contaminants and $\sigma_a$ is somewhat larger, say, about 0.0048 barns, so that $\Sigma_a \approx 0.0003851$ cm⁻¹.

†† The value of $\sigma_a$ given in the table is for pure $D_2O$. Commercially available heavy water contains small amounts of ordinary water and $\sigma_a$ in this case is somewhat larger.