

6. ATOMIC AND NUCLEAR PROPERTIES OF MATERIALS

Table 6.1 Abridged from pdg.lbl.gov/AtomicNuclearProperties by D.E. Groom (2015). See web pages for more detail about entries in this table and for several hundred other substances. Parentheses in the dE/dx and density columns indicate gases at 20°C and 1 atm. Boiling points are at 1 atm. Refractive indices n are evaluated at the sodium D line blend (589.2 nm); values $\gg 1$ in brackets indicate $(n - 1) \times 10^6$ for gases at 0°C and 1 atm.

| Material | Z | A | $\langle Z/A \rangle$ | Nucl.coll. length λ_T {g cm ⁻² } | Nucl.inter. length λ_I {g cm ⁻² } | Rad.len. X_0 {g cm ⁻² } | $dE/dx _{\min}$ { MeV g ⁻¹ cm ² } | Density {g cm ⁻³ {gℓ ⁻¹ } | Melting point (K) | Boiling point (K) | Refract. index @ Na D |
|--|-----|------------------|-----------------------|---|--|--|---|---|---|-------------------------|-----------------------------|
| H ₂ | 1 | 1.008(7) | 0.99212 | 42.8 | 52.0 | 63.04 | (4.103) | 0.071(0.084) | 13.81 | 20.28 | 1.11[132.] |
| D ₂ | 1 | 2.01410177803(8) | 0.49650 | 51.3 | 71.8 | 125.97 | (2.053) | 0.169(0.168) | 18.7 | 23.65 | 1.11[138.] |
| He | 2 | 4.002602(2) | 0.49967 | 51.8 | 71.0 | 94.32 | (1.937) | 0.125(0.166) | | 4.220 | 1.02[35.0] |
| Li | 3 | 6.94(2) | 0.43221 | 52.2 | 71.3 | 82.78 | 1.639 | 0.534 | 453.6 | 1615. | |
| Be | 4 | 9.0121831(5) | 0.44384 | 55.3 | 77.8 | 65.19 | 1.595 | 1.848 | 1560. | 2744. | |
| C diamond | 6 | 12.0107(8) | 0.49955 | 59.2 | 85.8 | 42.70 | 1.725 | 3.520 | | | 2.42 |
| C graphite | 6 | 12.0107(8) | 0.49955 | 59.2 | 85.8 | 42.70 | 1.742 | 2.210 | | | |
| N ₂ | 7 | 14.007(2) | 0.49976 | 61.1 | 89.7 | 37.99 | (1.825) | 0.807(1.165) | 63.15 | 77.29 | 1.20[298.] |
| O ₂ | 8 | 15.999(3) | 0.50002 | 61.3 | 90.2 | 34.24 | (1.801) | 1.141(1.332) | 54.36 | 90.20 | 1.22[271.] |
| F ₂ | 9 | 18.998403163(6) | 0.47372 | 65.0 | 97.4 | 32.93 | (1.676) | 1.507(1.580) | 53.53 | 85.03 | [195.] |
| Ne | 10 | 20.1797(6) | 0.49555 | 65.7 | 99.0 | 28.93 | (1.724) | 1.204(0.839) | 24.56 | 27.07 | 1.09[67.1] |
| Al | 13 | 26.9815385(7) | 0.48181 | 69.7 | 107.2 | 24.01 | 1.615 | 2.699 | 933.5 | 2792. | |
| Si | 14 | 28.0855(3) | 0.49848 | 70.2 | 108.4 | 21.82 | 1.664 | 2.329 | 1687. | 3538. | 3.95 |
| Cl ₂ | 17 | 35.453(2) | 0.47951 | 73.8 | 115.7 | 19.28 | (1.630) | 1.574(2.980) | 171.6 | 239.1 | [773.] |
| Ar | 18 | 39.948(1) | 0.45059 | 75.7 | 119.7 | 19.55 | (1.519) | 1.396(1.662) | 83.81 | 87.26 | 1.23[281.] |
| Ti | 22 | 47.867(1) | 0.45961 | 78.8 | 126.2 | 16.16 | 1.477 | 4.540 | 1941. | 3560. | |
| Fe | 26 | 55.845(2) | 0.46557 | 81.7 | 132.1 | 13.84 | 1.451 | 7.874 | 1811. | 3134. | |
| Cu | 29 | 63.546(3) | 0.45636 | 84.2 | 137.3 | 12.86 | 1.403 | 8.960 | 1358. | 2835. | |
| Ge | 32 | 72.630(1) | 0.44053 | 86.9 | 143.0 | 12.25 | 1.370 | 5.323 | 1211. | 3106. | |
| Sn | 50 | 118.710(7) | 0.42119 | 98.2 | 166.7 | 8.82 | 1.263 | 7.310 | 505.1 | 2875. | |
| Xe | 54 | 131.293(6) | 0.41129 | 100.8 | 172.1 | 8.48 | (1.255) | 2.953(5.483) | 161.4 | 165.1 | 1.39[701.] |
| W | 74 | 183.84(1) | 0.40252 | 110.4 | 191.9 | 6.76 | 1.145 | 19.300 | 3695. | 5828. | |
| Pt | 78 | 195.084(9) | 0.39983 | 112.2 | 195.7 | 6.54 | 1.128 | 21.450 | 2042. | 4098. | |
| Au | 79 | 196.966569(5) | 0.40108 | 112.5 | 196.3 | 6.46 | 1.134 | 19.320 | 1337. | 3129. | |
| Pb | 82 | 207.2(1) | 0.39575 | 114.1 | 199.6 | 6.37 | 1.122 | 11.350 | 600.6 | 2022. | |
| U | 92 | [238.02891(3)] | 0.38651 | 118.6 | 209.0 | 6.00 | 1.081 | 18.950 | 1408. | 4404. | |
| Air (dry, 1 atm) | | | 0.49919 | 61.3 | 90.1 | 36.62 | (1.815) | (1.205) | | 78.80 | [289] |
| Shielding concrete | | | 0.50274 | 65.1 | 97.5 | 26.57 | 1.711 | 2.300 | | | |
| Borosilicate glass (Pyrex) | | | 0.49707 | 64.6 | 96.5 | 28.17 | 1.696 | 2.230 | | | |
| Lead glass | | | 0.42101 | 95.9 | 158.0 | 7.87 | 1.255 | 6.220 | | | |
| Standard rock | | | 0.50000 | 66.8 | 101.3 | 26.54 | 1.688 | 2.650 | | | |
| Methane (CH ₄) | | | 0.62334 | 54.0 | 73.8 | 46.47 | (2.417) | (0.667) | 90.68 | 111.7 | [444.] |
| Ethane (C ₂ H ₆) | | | 0.59861 | 55.0 | 75.9 | 45.66 | (2.304) | (1.263) | 90.36 | 184.5 | |
| Propane (C ₃ H ₈) | | | 0.58962 | 55.3 | 76.7 | 45.37 | (2.262) | 0.493(1.868) | 85.52 | 231.0 | |
| Butane (C ₄ H ₁₀) | | | 0.59497 | 55.5 | 77.1 | 45.23 | (2.278) | (2.489) | 134.9 | 272.6 | |
| Octane (C ₈ H ₁₈) | | | 0.57778 | 55.8 | 77.8 | 45.00 | 2.123 | 0.703 | 214.4 | 398.8 | |
| Paraffin (CH ₃ (CH ₂) _n ≈23CH ₃) | | | 0.57275 | 56.0 | 78.3 | 44.85 | 2.088 | 0.930 | | | |
| Nylon (type 6, 6/6) | | | 0.54790 | 57.5 | 81.6 | 41.92 | 1.973 | 1.18 | | | |
| Polycarbonate (Lexan) | | | 0.52697 | 58.3 | 83.6 | 41.50 | 1.886 | 1.20 | | | |
| Polyethylene ([CH ₂ CH ₂] _n) | | | 0.57034 | 56.1 | 78.5 | 44.77 | 2.079 | 0.89 | | | |
| Polyethylene terephthalate (Mylar) | | | 0.52037 | 58.9 | 84.9 | 39.95 | 1.848 | 1.40 | | | |
| Polyimide film (Kapton) | | | 0.51264 | 59.2 | 85.5 | 40.58 | 1.820 | 1.42 | | | |
| Polymethylmethacrylate (acrylic) | | | 0.53937 | 58.1 | 82.8 | 40.55 | 1.929 | 1.19 | | | 1.49 |
| Polypropylene | | | 0.55998 | 56.1 | 78.5 | 44.77 | 2.041 | 0.90 | | | |
| Polystyrene ([C ₆ H ₅ CHCH ₂] _n) | | | 0.53768 | 57.5 | 81.7 | 43.79 | 1.936 | 1.06 | | | 1.59 |
| Polytetrafluoroethylene (Teflon) | | | 0.47992 | 63.5 | 94.4 | 34.84 | 1.671 | 2.20 | | | |
| Polyvinyltoluene | | | 0.54141 | 57.3 | 81.3 | 43.90 | 1.956 | 1.03 | | | 1.58 |
| Aluminum oxide (sapphire) | | | 0.49038 | 65.5 | 98.4 | 27.94 | 1.647 | 3.970 | 2327. | 3273. | 1.77 |
| Barium fluoride (BaF ₂) | | | 0.42207 | 90.8 | 149.0 | 9.91 | 1.303 | 4.893 | 1641. | 2533. | 1.47 |
| Bismuth germanate (BGO) | | | 0.42065 | 96.2 | 159.1 | 7.97 | 1.251 | 7.130 | 1317. | | 2.15 |
| Carbon dioxide gas (CO ₂) | | | 0.49989 | 60.7 | 88.9 | 36.20 | 1.819 | (1.842) | | | [449.] |
| Solid carbon dioxide (dry ice) | | | 0.49989 | 60.7 | 88.9 | 36.20 | 1.787 | 1.563 | Sublimes at 194.7 K | | |
| Cesium iodide (CsI) | | | 0.41569 | 100.6 | 171.5 | 8.39 | 1.243 | 4.510 | 894.2 | 1553. | 1.79 |
| Lithium fluoride (LiF) | | | 0.46262 | 61.0 | 88.7 | 39.26 | 1.614 | 2.635 | 1121. | 1946. | 1.39 |
| Lithium hydride (LiH) | | | 0.50321 | 50.8 | 68.1 | 79.62 | 1.897 | 0.820 | 965. | | |
| Lead tungstate (PbWO ₄) | | | 0.41315 | 100.6 | 168.3 | 7.39 | 1.229 | 8.300 | 1403. | | 2.20 |
| Silicon dioxide (SiO ₂ , fused quartz) | | | 0.49930 | 65.2 | 97.8 | 27.05 | 1.699 | 2.200 | 1986. | 3223. | 1.46 |
| Sodium chloride (NaCl) | | | 0.47910 | 71.2 | 110.1 | 21.91 | 1.847 | 2.170 | 1075. | 1738. | 1.54 |
| Sodium iodide (NaI) | | | 0.42697 | 93.1 | 154.6 | 9.49 | 1.305 | 3.667 | 933.2 | 1577. | 1.77 |
| Water (H ₂ O) | | | 0.55509 | 58.5 | 83.3 | 36.08 | 1.992 | 1.000 | 273.1 | 373.1 | 1.33 |
| Silica aerogel | | | 0.50093 | 65.0 | 97.3 | 27.25 | 1.740 | 0.200 | (0.03 H ₂ O, 0.97 SiO ₂) | | |

| Material | Dielectric constant ($\kappa = \epsilon/\epsilon_0$) () is $(\kappa-1)\times 10^6$ for gas | Young's modulus [10^6 psi] | Coeff. of thermal expansion [10^{-6} cm/cm- $^{\circ}$ C] | Specific heat [cal/g- $^{\circ}$ C] | Electrical resistivity [$\mu\Omega$ cm(@ $^{\circ}$ C)] | Thermal conductivity [cal/cm- $^{\circ}$ C-sec] |
|----------------|---|----------------------------------|---|--|---|--|
| H ₂ | (253.9) | — | — | — | — | — |
| He | (64) | — | — | — | — | — |
| Li | — | — | 56 | 0.86 | 8.55(0 $^{\circ}$) | 0.17 |
| Be | — | 37 | 12.4 | 0.436 | 5.885(0 $^{\circ}$) | 0.38 |
| C | — | 0.7 | 0.6–4.3 | 0.165 | 1375(0 $^{\circ}$) | 0.057 |
| N ₂ | (548.5) | — | — | — | — | — |
| O ₂ | (495) | — | — | — | — | — |
| Ne | (127) | — | — | — | — | — |
| Al | — | 10 | 23.9 | 0.215 | 2.65(20 $^{\circ}$) | 0.53 |
| Si | 11.9 | 16 | 2.8–7.3 | 0.162 | — | 0.20 |
| Ar | (517) | — | — | — | — | — |
| Ti | — | 16.8 | 8.5 | 0.126 | 50(0 $^{\circ}$) | — |
| Fe | — | 28.5 | 11.7 | 0.11 | 9.71(20 $^{\circ}$) | 0.18 |
| Cu | — | 16 | 16.5 | 0.092 | 1.67(20 $^{\circ}$) | 0.94 |
| Ge | 16.0 | — | 5.75 | 0.073 | — | 0.14 |
| Sn | — | 6 | 20 | 0.052 | 11.5(20 $^{\circ}$) | 0.16 |
| Xe | — | — | — | — | — | — |
| W | — | 50 | 4.4 | 0.032 | 5.5(20 $^{\circ}$) | 0.48 |
| Pt | — | 21 | 8.9 | 0.032 | 9.83(0 $^{\circ}$) | 0.17 |
| Pb | — | 2.6 | 29.3 | 0.038 | 20.65(20 $^{\circ}$) | 0.083 |
| U | — | — | 36.1 | 0.028 | 29(20 $^{\circ}$) | 0.064 |