**Mechanical Properties Of Elements from** [**http://matweb.com/**](http://matweb.com/)**.**

**Lithium**

Hardness, Vickers Max 5

Tensile Strength, Ultimate Max 15 MPa

**Beryllium**

Hardness, Rockwell B 75–85

Tensile Strength, Ultimate 370 MPa

Tensile Strength, Yield 240 MPa

Elongation at Break 3%

Modulus of Elasticity 303 GPa

Compressive Yield Strength 270 MPa Yield at 0,2% offset (10% higher than tensile yield strength)

Poisson's Ratio 0,07–0,18 values between 0,07 and 0,18 have been reported for beryllium

Charpy Impact 1,5–5,5 J (1,11–4,06 ft-lb) Notch status unknown

Fatigue Strength 160 MPa 107 cycles; Kt=3,07 and R = 0,1

Fatigue Strength 240 MPa 104 cycles; Kt=3,07 and R = 0,1

Fatigue Strength 240 MPa smooth; 107 cycles (=yield strength)

Fracture Toughness 10,6–12,3 MPa-mЅ KIC for hot-pressed structural grades

Shear Modulus 135 GPa

Shear Strength 345 MPa hot-pressed block

Shear Strength 480 MPa cross-rolled sheet

**Boron (Crystalline)**

Knoop Microhardness 99,9% pure is 3300 (100 g load)

9,3 Mohs

Tensile Strength, Ultimate 2,6–3,1 MPa

Compressive Yield Strength Max 0,5 MPa B2O3 inclusions

**Boron (Amorphous)**

Tensile Strength, Ultimate 1,6–2,4 MPa

Modulus of Elasticity 0,44 GPa in tension

**Diamond (С)**

Hardness, Knoop 8000

Knoop Microhardness 56–102 (001) face

Knoop Microhardness 58–88 (110),(111) faces

Knoop Microhardness 79 GPa

Vickers Microhardness 88–147 in GPa; (001) face

Vickers Microhardness 98 in GPa; (111) face

Hardness, Mohs 10

Abrasive Hardness 140000

Modulus of Elasticity 700–1200 GPa

Compressive Yield Strength 8680–16530 MPa

Poisson's Ratio 0,1–0,29

Fracture Toughness 3,4 MPa-mЅ

**Sodium**

Hardness, Vickers 0,1

Tensile Strength, Ultimate Max 10 MPa

**Magnesium (Annealed Sheet)**

Hardness, Brinell 40 500 kg load/10 mm ball

Tensile Strength, Ultimate 160–196 MPa

Tensile Strength, Yield 90–105 MPa

Elongation at Break 3–15%

Modulus of Elasticity 44 GPa

Compressive Yield Strength 69–83 MPa

Poisson's Ratio 0,35

Shear Modulus 19 GPa Calculated

Coefficient of Friction 0,36 versus magnesium at 20°C

**Magnesium (Hard-Rolled Sheet)**

Hardness, Brinell 46 500 kg load/10 mm ball

Tensile Strength, Ultimate 180–220 MPa

Tensile Strength, Yield 115–140 MPa

Elongation at Break 2–10%

Compressive Yield Strength 105–115 MPa

**Magnesium (Extruded)**

Hardness, Brinell 35 500 kg load/10 mm ball

Tensile Strength, Ultimate 165–205 MPa

Tensile Strength, Yield 69–105 MPa

Elongation at Break 5–8%

Compressive Yield Strength 34–55 MPa

**Magnesium (Sand Cast)**

Hardness, Brinell 30 500 kg load/10 mm ball

Tensile Strength, Ultimate 90 MPa

Tensile Strength, Yield 21 MPa

Elongation at Break 2–6%

Compressive Yield Strength 21 MPa

**Aluminum**

Hardness, Vickers 15 Annealed

Modulus of Elasticity 68 GPa

Shear Modulus 25 GPa

**Silicon**

Knoop Microhardness 11270 N/mm2

Modulus of Elasticity 112,4 GPa

Compressive Yield Strength 120 MPa

Bulk Modulus 98,74 GPa

Poisson's Ratio 0,28

Shear Modulus 49 GPa Calculated

**Calcium (Annealed)**

Hardness, Brinell 17

Tensile Strength, Ultimate 40 MPa

Tensile Strength, Yield 13,7 MPa

Elongation at Break 52%

Modulus of Elasticity 23,4 GPa

Bulk Modulus 15,2 GPa

Poisson's Ratio 0,31

Shear Modulus 7,38 GPa

**Calcium (Rolled)**

Hardness, Vickers 17 Unknown Heat Treatment

Tensile Strength, Ultimate 110 MPa

Tensile Strength, Yield 84,8 MPa

Elongation at Break 7%

**Scandium**

Hardness, Vickers 132 (0001) face

Hardness, Vickers 36 (0101) face

Tensile Strength, Ultimate 255 MPa

Tensile Strength, Yield 173 MPa

Elongation at Break 5%

Modulus of Elasticity 74,4 GPa in tension

Bulk Modulus 56,6 GPa

Poisson's Ratio 0,279

Shear Modulus 29,1 GPa

**Titanium**

Hardness, Brinell 70 electrolytic Ti

Hardness, Vickers 60

Tensile Strength, Ultimate 220 MPa

Tensile Strength, Yield 140 MPa

Elongation at Break 54%

Modulus of Elasticity 116 GPa

Poisson's Ratio 0,34

**Vanadium (Vacuum Annealed Sheet)**

Hardness, Brinell 137 Converted from Rockwell B, (500 kg load)

Hardness, Knoop 173 Converted from Rockwell B

Hardness, Rockwell A 51,1 Converted from Rockwell B

Hardness, Rockwell B 83

Hardness, Vickers 159 Converted from Rockwell B

Tensile Strength, Ultimate 536 MPa

Tensile Strength, Yield 454 MPa

Elongation at Break 20% in 50 mm

Modulus of Elasticity 125,5 GPa

Poisson's Ratio 0,36

Shear Modulus 46,4 GPa

**Vanadium (Cold Rolled)**

Hardness, Brinell 165 Converted from Vickers, (3000 kg load)

Hardness, Rockwell A 52 Converted from Vickers

Hardness, Rockwell B 100

Hardness, Rockwell C 3 Converted from Vickers, Value below normal HRC range, for comparison only

Hardness, Vickers 170

Tensile Strength, Ultimate 800 MPa

Tensile Strength, Yield 776 MPa

Elongation at Break 2% in 50 mm

**Vanadium (Hot Rolled Bar)**

Hardness, Brinell 142 Converted from Rockwell B, (500 kg load)

Hardness, Knoop 180 Converted from Rockwell B

Hardness, Rockwell A 52,3 Converted from Rockwell B

Hardness, Rockwell B 85

Hardness, Vickers 165 Converted from Rockwell B

Tensile Strength, Ultimate 472 MPa

Tensile Strength, Yield 439 MPa

Elongation at Break 27% in 50 mm

**Vanadium (Vacuum Annealed Wire)**

Hardness, Brinell 126 Converted from Rockwell A (500 kg load)

Hardness, Knoop 158 Converted from Rockwell A

Hardness, Rockwell A 48

Hardness, Rockwell B 78 Converted from Rockwell A

Hardness, Vickers 141 Converted from Rockwell A

Tensile Strength, Ultimate 538 MPa

Tensile Strength, Yield 463 MPa

Elongation at Break 25% in 50 mm

**Vanadium (Cold Drawn Wire)**

Hardness, Brinell 151 Converted from Rockwell A, (500 kg load)

Hardness, Knoop 192 Converted from Rockwell A

Hardness, Rockwell A 54

Hardness, Rockwell B 88 Converted from Rockwell A

Hardness, Vickers 176 Converted from Rockwell A

Tensile Strength, Ultimate 911 MPa

Tensile Strength, Yield 765 MPa

Elongation at Break 6,8% in 50 mm

**Chromium (Annealed)**

Hardness, Brinell 80 Converted from Vickers for 500 kg load/10 mm ball Brinell test

Hardness, Knoop 102 Converted from Vickers

Hardness, Rockwell B 48 Converted from Vickers

Hardness, Vickers 90

Charpy Impact, Unnotched 2 J (1,48 ft-lb) Unspecified Heat Treatment

**Chromium (Recrystallized)**

Tensile Strength, Ultimate 282 MPa

Elongation at Break 0%

Modulus of Elasticity 248 GPa

**Chromium (As-Swaged)**

Hardness, Brinell 125

Hardness, Knoop 144 Converted from Brinell

Hardness, Rockwell B 72 Converted from Brinell

Hardness, Vickers 131 Converted from Brinell

Tensile Strength, Ultimate 413 MPa

Tensile Strength, Yield 362 MPa

Elongation at Break 44%

**Manganese**

Hardness, Brinell 460 Converted from Vickers for 3000 kg load/10 mm ball Brinell test

Hardness, Rockwell A 75 Converted from Vickers

Hardness, Rockwell C 48 Converted from Vickers

Hardness, Vickers 500

Tensile Strength, Ultimate 496 MPa γ-Phase

Tensile Strength, Yield 241 MPa γ-Phase

Modulus of Elasticity 159 GPa

Bulk Modulus 92,6 GPa

Poisson's Ratio 0,35

Shear Modulus 76,4 GPa

**Iron**

Hardness, Brinell 146 Converted from Vickers for 3000 kg load/10 mm ball Brinell test

Hardness, Rockwell A 49

Hardness, Rockwell B 79

Hardness, Vickers 150

Tensile Strength, Yield 50 MPa 0,5% strain; after zone refining

Modulus of Elasticity 200 GPa

Bulk Modulus 166 GPa

Poisson's Ratio 0,291

Shear Modulus 87 GPa Calculated

**Cobalt**

Hardness, Brinell 125

Hardness, Vickers 253

Tensile Strength, Yield 225 MPa

Modulus of Elasticity 211 GPa

Poisson's Ratio 0,32

Shear Modulus 82,6 GPa

**Nickel (Annealed)**

Hardness, Vickers 75

Tensile Strength, Ultimate 45 MPa

Modulus of Elasticity 207 GPa

Poisson's Ratio 0,31

Shear Modulus 76 GPa

**Nickel (Typical)**

Tensile Strength, Ultimate 317 MPa

Tensile Strength, Yield 59 MPa

Elongation at Break 30%

Shear Modulus 76 GPa

**Copper (Annealed)**

Hardness, Vickers 50

Tensile Strength, Ultimate 210 MPa

Tensile Strength, Yield 33,3 MPa

Elongation at Break 60%

Modulus of Elasticity 110 GPa

Bulk Modulus 140 GPa

Poisson's Ratio 0,343

Shear Modulus 46 GPa

**Copper (Cold-Worked)**

Hardness, Brinell 89 Converted from Vickers for 500 kg load/10 mm ball Brinell test

Hardness, Rockwell A 35

Hardness, Rockwell B 51

Hardness, Vickers 100

Bulk Modulus 140 GPa

Poisson's Ratio 0,35

**Copper (Cold Drawn)**

Hardness, Rockwell B 37

Tensile Strength, Ultimate 344 MPa

Tensile Strength, Yield 333,4 MPa

Elongation at Break 14%

Bulk Modulus 140 GPa

Poisson's Ratio 0,364

**Zinc**

Hardness, Vickers 30

Tensile Strength, Ultimate 37 MPa cast sample

Modulus of Elasticity 96,5 GPa

**Gallium**

Hardness, Vickers 50

**Germanium**

Knoop Microhardness 7644 N/mm2

Modulus of Elasticity 130 GPa Average of three axes

Poisson's Ratio 0,3 Calculated

Shear Modulus 50 GPa Average of three axes

**Selenium**

Knoop Microhardness 350 N/mm2 Gray Selenium

Modulus of Elasticity 57,9 GPa

Shear Modulus 6,46 GPa

**Rubidium**

Modulus of Elasticity 2,35 GPa

**Strontium**

Bulk Modulus 11,61 GPa

**Yttrium**

Hardness, Vickers 40 highly anisotropic

Tensile Strength, Ultimate 150 MPa

Tensile Strength, Yield 67 MPa

Elongation at Break 34% in 25 mm

Modulus of Elasticity 63,5 GPa

Bulk Modulus 41,2 GPa

Poisson's Ratio 0,243

Shear Modulus 25,6 GPa

**Zirconium**

Hardness, Brinell 145 Converted from Vickers for 3000 kg load/10 mm ball, Annealed sample

Hardness, Rockwell A 49 annealed sample

Hardness, Rockwell B 78 Annealed sample

Hardness, Vickers 150 annealed sample

Tensile Strength, Ultimate 330 MPa Annealed

Tensile Strength, Yield 230 MPa Annealed

Elongation at Break 32% Annealed

Modulus of Elasticity 94,5 GPa

Poisson's Ratio 0,34

Shear Modulus 40 GPa Calculated

**Niobium (Columbium) (Annealed Sample)**

Hardness, Vickers 80

Tensile Strength, Ultimate 300 MPa

Tensile Strength, Yield 207 MPa

Elongation at Break 30%

Modulus of Elasticity 103 GPa

Poisson's Ratio 0,38

Shear Modulus 37,5 GPa

**Niobium (Columbium) (Cold-Worked)**

Hardness, Brinell 126 Converted from Vickers for 3000 kg load/10 mm ball Brinell test

Hardness, Rockwell A 45

Hardness, Rockwell B 71

Hardness, Vickers 130

Tensile Strength, Ultimate 600 MPa

**Niobium (Columbium) (Wrought)**

Hardness, Brinell 152 Converted from Vickers for 3000 kg load/10 mm ball Brinell test

Hardness, Knoop 175

Hardness, Rockwell B 81,7

Hardness, Vickers 160

Tensile Strength, Ultimate 585 MPa

Elongation at Break 5%

**Molybdenum (Annealed)**

Hardness, Brinell 225 Converted from Vickers for 3000 kg load/10 mm ball Brinell test

Hardness, Rockwell A 60 Converted from Vickers

Hardness, Rockwell B 98 Converted from Vickers

Hardness, Rockwell C 19 Converted from Vickers

Hardness, Vickers 230

Tensile Strength, Ultimate 324 MPa

Tensile Strength, Ultimate 350 MPa Single crystal

Modulus of Elasticity 330 GPa; 275 GPa at 1000°C

Compressive Yield Strength 400 MPa 0,01% Yield

Bulk Modulus 272 GPa

Shear Modulus 120 GPa

Shear Strength 500 MPa torsional strain rate 0,25/sec

**Molybdenum (Recrystallized)**

Tensile Strength, Ultimate 415 MPa

Tensile Strength, Yield 300 MPa 0,2% Offset

Elongation at Break Max 40% in 50 mm

**Molybdenum (Stress Relieved Condition)**

Tensile Strength, Ultimate 515 MPa

Tensile Strength, Yield 415 MPa 0,2% Offset

Elongation at Break 2–17% in 50 mm

**Technetium (Annealed)**

Hardness, Brinell 112

Hardness, Vickers 151

Tensile Strength, Ultimate 800 MPa

Tensile Strength, Yield 320 MPa 0,2% offset

Elongation at Break 30% in 25 mm

Modulus of Elasticity 322 GPa in tension

Bulk Modulus 281 GPa

Poisson's Ratio 0,31

Shear Modulus 123 GPa

**Technetium (As-Rolled)**

Hardness, Brinell 442

Hardness, Vickers 394

Tensile Strength, Ultimate 1510 MPa

Tensile Strength, Yield 1290 MPa 0,2% offset

Elongation at Break 4% in 25 mm

**Ruthenium (Annealed)**

Hardness, Brinell 220 Converted from Vickers for 3000 kg load/10 mm ball Brinell test

Hardness, Rockwell A 60 Converted from Vickers

Hardness, Rockwell B 96 Converted from Vickers

Hardness, Rockwell C 18 Converted from Vickers

Hardness, Vickers 220

Tensile Strength, Ultimate 370 MPa

Modulus of Elasticity 414 GPa

**Ruthenium (Hot Rolled Bar)**

Tensile Strength, Ultimate 540 MPa

Modulus of Elasticity 414 GPa

**Rhodium (Annealed)**

Hardness, Brinell 89 Converted from Vickers for 500 kg load/10 mm ball Brinell test

Hardness, Rockwell A 35 Converted from Vickers

Hardness, Rockwell B 51 Converted from Vickers

Hardness, Vickers 100

Tensile Strength, Ultimate 951 MPa

Modulus of Elasticity 359 GPa

**Rhodium (As-Plated)**

Hardness, Brinell 722 Converted from Vickers for 3000 kg load/10 mm ball Brinell test

Hardness, Rockwell A 83 Converted from Vickers

Hardness, Rockwell C 63 Converted from Vickers

Hardness, Vickers 800

Tensile Strength, Ultimate 700 MPa

**Rhodium (Hardened)**

Tensile Strength, Ultimate 2068 MPa

**Palladium**

Hardness, Vickers 37 Annealed

Tensile Strength, Ultimate 180 MPa Annealed

Modulus of Elasticity 117 GPa

Poisson's Ratio 0,39

Shear Modulus 49 GPa Calculated

**Silver**

Hardness, Vickers 25 Annealed

Tensile Strength, Ultimate 140 MPa Annealed

Modulus of Elasticity 76 GPa

Poisson's Ratio 0,37 Annealed

Poisson's Ratio 0,39 Hard drawn

Shear Modulus 32 GPa Calculated; Annealed

**Cadmium**

Hardness, Brinell 16–24

Hardness, Vickers 22

Tensile Strength, Ultimate 75 MPa

Elongation at Break 50% in 25 mm

Modulus of Elasticity 55,2 GPa

Poisson's Ratio 0,33

Shear Modulus 19,2 GPa

**Indium**

Hardness, Brinell 0,9

Hardness, Vickers Max 10

Tensile Strength, Ultimate 4,5 MPa Annealed

Modulus of Elasticity 12,7 GPa in tension

Compressive Yield Strength 2,14 MPa

Poisson's Ratio 0,4498

Shear Modulus 5 GPa Calculated

**Tin**

Hardness, Brinell 3,9

Tensile Strength, Ultimate 220 MPa

Modulus of Elasticity 41,4 GPa

Poisson's Ratio 0,33

Shear Modulus 18 GPa Calculated

**Antimony**

Hardness, Brinell 30–58

Hardness, Vickers 30–60

Tensile Strength, Ultimate 11,4 MPa

Modulus of Elasticity 77,759 GPa

Shear Modulus 19 GPa

**Tellurium**

Hardness, Brinell 25

Tensile Strength, Ultimate 11 MPa

Modulus of Elasticity 40 GPa

Poisson's Ratio 0,33

Shear Modulus 15,16 GPa

**Cesium**

Bulk Modulus 1,57 GPa

**Barium**

Modulus of Elasticity 12,8 GPa

Bulk Modulus 10,2 GPa

Poisson's Ratio 0,28

Shear Modulus 6 GPa Calculated

**Lanthanum**

Hardness, Vickers 28

Tensile Strength, Ultimate 130 MPa

Tensile Strength, Yield 125 MPa

Elongation at Break 7,9%

Modulus of Elasticity 36,6 GPa in tension

Bulk Modulus 27,9 GPa

Poisson's Ratio 0,28

Shear Modulus 14,3 GPa

**Cerium**

Hardness, Vickers 24

Tensile Strength, Ultimate 100 MPa

Tensile Strength, Yield 91 MPa

Modulus of Elasticity 41,4 GPa

Bulk Modulus 21,5 GPa

Poisson's Ratio 0,248

Shear Modulus 13,5 GPa

**Praseodymium**

Hardness, Vickers 20

Tensile Strength, Ultimate 110 MPa

Tensile Strength, Yield 100 MPa

Elongation at Break 15%

Modulus of Elasticity 37,3 GPa in tension

Bulk Modulus 28,8 GPa

Poisson's Ratio 0,281

Shear Modulus 14,8 GPa

**Neodymium**

Hardness, Vickers 18

Tensile Strength, Ultimate 170 MPa

Tensile Strength, Yield 165 MPa

Elongation at Break 25%

Modulus of Elasticity 41,4 GPa

Bulk Modulus 31,8 GPa

Poisson's Ratio 0,281

Shear Modulus 16,3 GPa

**Promethium**

Hardness, Knoop 63

Tensile Strength, Ultimate 160 MPa

Tensile Strength, Yield 70 MPa

Elongation at Break 25%

Modulus of Elasticity 50 GPa (tension)

Bulk Modulus 33 GPa

Poisson's Ratio 0,28

Shear Modulus 18 GPa

**Samarium**

Hardness, Vickers 39

Tensile Strength, Ultimate 120–156 MPa different sources report in this range

Tensile Strength, Yield 68–112 MPa

Elongation at Break 17%

Modulus of Elasticity 49,7 GPa in tension

Bulk Modulus 37,8 GPa

Poisson's Ratio 0,274

Shear Modulus 19,5 GPa

**Europium**

Hardness, Vickers 17

Modulus of Elasticity 18,2 GPa in tension

Bulk Modulus 8,3 GPa

Poisson's Ratio 0,152

Shear Modulus 7,9 GPa

**Gadolinium**

Hardness, Vickers 37 polycrystalline

Tensile Strength, Ultimate 190 MPa

Tensile Strength, Yield 173 MPa

Elongation at Break 37%

Modulus of Elasticity 54,8 GPa in tension

Bulk Modulus 37,9 GPa

Poisson's Ratio 0,259

Shear Modulus 24 GPa Calculated

**Terbium**

Hardness, Vickers 38 polycrystalline

Tensile Strength, Ultimate 140 MPa

Tensile Strength, Yield 60 MPa

Elongation at Break 12%

Modulus of Elasticity 55,7 GPa in tension

Bulk Modulus 38,7 GPa

Poisson's Ratio 0,26 Calculated

Shear Modulus 22,1 GPa

**Dysprosium**

Hardness, Vickers 44

Tensile Strength, Ultimate 246 MPa

Tensile Strength, Yield 225 MPa

Elongation at Break 30%

Modulus of Elasticity 61,4 GPa in tension

Bulk Modulus 40,5 GPa

Poisson's Ratio 0,237

Shear Modulus 24,7 GPa

**Holmium**

Hardness, Vickers 46

Tensile Strength, Ultimate 259 MPa

Tensile Strength, Yield 221 MPa

Modulus of Elasticity 64,8 GPa in tension

Bulk Modulus 40,2 GPa

Poisson's Ratio 0,231

Shear Modulus 26,3 GPa

**Erbium**

Hardness, Vickers 42

Tensile Strength, Ultimate 136 MPa

Tensile Strength, Yield 60 MPa

Elongation at Break 11,5%

Reduction of Area 11,9%

Modulus of Elasticity 69,9 GPa in tension

Bulk Modulus 44,4 GPa

Poisson's Ratio 0,237

Shear Modulus 28,3 GPa

**Thulium**

Hardness, Vickers 48

Tensile Strength, Ultimate 140 MPa

Tensile Strength, Yield 60 MPa

Elongation at Break 12%

Modulus of Elasticity 74 GPain tension

Bulk Modulus 44,5 GPa

Poisson's Ratio 0,213

Shear Modulus 30,5 GPa

**Ytterbium**

Hardness, Vickers 17

Tensile Strength, Ultimate 72 MPa

Tensile Strength, Yield 66 MPa

Elongation at Break 43%

Modulus of Elasticity 23,7 GPa in tension

Bulk Modulus 30,5 GPa

Poisson's Ratio 0,207

Shear Modulus 9,9 GPa

**Lutetium**

Hardness, Vickers 44

Tensile Strength, Ultimate 140 MPa

Tensile Strength, Yield 60 MPa

Elongation at Break 12%

Modulus of Elasticity 68,6 GPa in tension

Bulk Modulus 47,6 GPa

Poisson's Ratio 0,261

Shear Modulus 27,2 GPa

**Hafnium (Rod)**

Tensile Strength, Ultimate 485 MPa

Tensile Strength, Yield 240 MPa

Elongation at Break 25%

**Hafnium (Plate)**

Tensile Strength, Ultimate 450 MPa Longitudinal

Tensile Strength, Ultimate 470 MPa Transverse

Tensile Strength, Yield 195 MPa Longitudinal

Tensile Strength, Yield 310 MPa Transverse

Elongation at Break 25% Longitudinal or Transverse

**Hafnium (Strip)**

Tensile Strength, Ultimate 450 MPa Longitudinal or Transverse

Tensile Strength, Yield 170 MPa Longitudinal

Tensile Strength, Yield 275 MPa Transverse

Elongation at Break 30% Longitudinal or Transverse

**Tantalum (Annealed)**

Hardness, Brinell 95 Converted from Vickers for 3000 kg load/10 mm ball Brinell test

Hardness, Rockwell A 35 Converted from Vickers

Hardness, Rockwell B 51 Converted from Vickers

Hardness, Vickers 100

Tensile Strength, Ultimate 450 MPa

Modulus of Elasticity 186 GPa

Poisson's Ratio 0,35

Fatigue Strength 230 MPa 50,000,000 cycles, E-beam melted sample; rotating beam test,

Shear Modulus 69 GPa

**Tantalum (Cold Worked)**

Hardness, Brinell 195 Converted from Vickers for 3000 kg load/10 mm ball Brinell test

Hardness, Rockwell A 56 Converted from Vickers

Hardness, Rockwell B 92 Converted from Vickers

Hardness, Rockwell C 12 Converted from Vickers

Hardness, Vickers 200

Tensile Strength, Ultimate 900 MPa

**Tungsten**

Hardness, Brinell 294 Estimated from Vickers

Hardness, Knoop 318 Estimated from Vickers

Hardness, Rockwell A 66 Estimated from Vickers

Hardness, Rockwell C 31 Estimated from Vickers

Hardness, Vickers 310

Tensile Strength, Ultimate 980 MPa

Tensile Strength, Yield 750 MPa 0,2% Offset

Modulus of Elasticity 400 GPa

Poisson's Ratio 0,28

Shear Modulus 175 GPa Calculated

Shear Strength 400 MPa Average value for W blanks

**Tungsten (drawn wire)**

Hardness, Brinell 444 Converted from Vickers for 3000 kg load/10 mm ball Brinell test Drawn and annealed

Hardness, Knoop 505 Estimated from Vickers,

Hardness, Rockwell A 74 Drawn and annealed

Hardness, Rockwell C 47 Drawn and annealed

Hardness, Vickers 480 Drawn and annealed

Tensile Strength, Yield 450 MPa

**Rhenium (Annealed)**

Hardness, Brinell 165 Converted from Vickers for 3000 kg load/10 mm ball Brinell test

Hardness, Rockwell A 52 Converted from Vickers

Hardness, Rockwell B 85 Converted from Vickers

Hardness, Rockwell C 3 Value below normal HRC range, for comparison only

Hardness, Vickers 170

Tensile Strength, Ultimate 1070 MPa Value at 800°C is 620 MPa, Value at 1200°C is 410 MPa

Tensile Strength, Yield 290 MPa

Elongation at Break 15–25%

Modulus of Elasticity 469 GPa

Poisson's Ratio 0,296

Shear Modulus 176 GPa

**Rhenium (Deformed)**

Hardness, Brinell 500 Converted from Vickers for 3000 kg load/10 mm ball Brinell test

Hardness, Rockwell A 76 Converted from Vickers

Hardness, Rockwell C 50 Converted from Vickers

Hardness, Vickers 550 15% Cold-Worked

Tensile Strength, Ultimate 2100 MPa

Elongation at Break 1–3%

Modulus of Elasticity 460 GPa

**Osmium (Annealed)**

Hardness, Brinell 293 Converted from Vickers for 3000 kg load/10 mm ball Brinell test

Hardness, Rockwell A 66 Converted from Vickers

Hardness, Rockwell C 30 Converted from Vickers

Hardness, Vickers 300

Tensile Strength, Ultimate 1000 MPa

Modulus of Elasticity 560 GPa

**Osmium (Cold-Worked)**

Hardness, Brinell 580 Converted from Vickers for 3000 kg load/10 mm ball Brinell test

Hardness, Rockwell A 80

Hardness, Rockwell C 57

Hardness, Vickers 670

**Osmium (Arc-Melted)**

Hardness, Brinell 722 Converted from Vickers for 3000 kg load/10 mm ball Brinell test

Hardness, Knoop 822 Converted from Vickers

Hardness, Rockwell A 83,4 Converted from Vickers

Hardness, Rockwell C 64 Converted from Vickers

Hardness, Vickers 800

**Iridium (Annealed)**

Hardness, Brinell 352 Converted from Vickers for 3000 kg load/10 mm ball Brinell test

Hardness, Rockwell A 69

Hardness, Rockwell C 37

Hardness, Vickers 370

Tensile Strength, Ultimate 1000 MPa

Modulus of Elasticity 524 GPa

Poisson's Ratio 0,26

Shear Modulus 232 GPa Calculated

**Iridium (Cold-Drawn)**

Hardness, Brinell 565 Converted from Vickers for 3000 kg load/10 mm ball Brinell test

Hardness, Rockwell A 80

Hardness, Rockwell C 56

Hardness, Vickers 650

Tensile Strength, Ultimate 2000 MPa

**Platinum (CP Grade, Annealed)**

Hardness, Vickers 40

Tensile Strength, Ultimate 125–165 MPa

Elongation at Break 35% in 50 mm

Modulus of Elasticity 171 GPa static in tension

Poisson's Ratio 0,39

Shear Modulus 62 GPa Calculated value

**Platinum (CP Grade, Hard Drawn–50% Cold Worked)**

Hardness, Knoop 103 Estimated from Vickers,

Hardness, Rockwell B 49 Estimated from Vickers,

Hardness, Vickers 90

Tensile Strength, Ultimate 205–240 MPa

Elongation at Break 1–3% in 50 mm

Modulus of Elasticity 156 GPa static in tension

Shear Modulus 56 GPa Calculated value

**Platinum (Thermocouple Quality, Annealed)**

Tensile Strength, Ultimate 143 MPa

**Gold**

Hardness, Vickers 25

Tensile Strength, Ultimate 120 MPa Annealed

Elongation at Break 30%

Modulus of Elasticity 77,2 GPa 60% Cold Worked

Poisson's Ratio 0,42

Shear Modulus 32 GPa 60% Cold Worked; Calculated Value

**Thallium**

Hardness, Brinell 2

Hardness, Vickers 2

Tensile Strength, Ultimate 7,5 MPa

Elongation at Break 40% in 125 mm

**Lead**

Hardness, Brinell 4,2 Cast

Hardness, Vickers 5

Tensile Strength, Ultimate 18 MPa

Modulus of Elasticity 14 GPa

Poisson's Ratio 0,42

**Bismuth**

Hardness, Brinell 7

Modulus of Elasticity 31,7 GPa

Poisson's Ratio 0,33

Shear Modulus 14 GPa Calculated

**Thorium**

Hardness, Vickers 35–114 References report a wide range of values

Tensile Strength, Ultimate 200 MPa

Tensile Strength, Yield 144 MPa 0,2% offset

Elongation at Break 34%

Modulus of Elasticity 73,1 GPa

Compressive Yield Strength 200 MPa Approximately equal to tensile

Bulk Modulus 57,7 GPa

Poisson's Ratio 0,27

Fatigue Strength 97 MPa reversed bend test endurance limit

Shear Modulus 28 GPa

**Protactinium**

Bulk Modulus 157 GPa

**Uranium (Cast)**

Hardness, Brinell 185 Converted from Vickers for 3000 kg load/10 mm ball Brinell test Unspecified heat treatment

Hardness, Rockwell A 55 Unspecified heat treatment

Hardness, Rockwell B 90 Unspecified heat treatment

Hardness, Rockwell C 10 Unspecified heat treatment

Hardness, Vickers 190 Unspecified heat treatment

Tensile Strength, Ultimate 400 MPa

Tensile Strength, Yield 200 MPa

Elongation at Break 4%

Modulus of Elasticity 190 GPa

Poisson's Ratio 0,22

Shear Modulus 86 GPa Calculated

**Uranium (Beta-Annealed)**

Tensile Strength, Ultimate 615 MPa

**Uranium (Wrought Α Phase)**

Tensile Strength, Ultimate 1150 MPa

Tensile Strength, Yield 740 MPa

Elongation at Break 14%

**Neptunium**

Hardness, Vickers 346

Bulk Modulus 118 GPa

Shear Modulus 80 GPa

**Plutonium**

Hardness, Brinell 242 Converted from Vickers for 3000 kg load/10 mm ball Brinell test

Hardness, Rockwell A 62

Hardness, Rockwell C 22

Hardness, Vickers 250

Tensile Strength, Ultimate 400 MPa Cast α

Tensile Strength, Yield 275 MPa Cast α

Elongation at Break 0,2–0,5% Cast α

Modulus of Elasticity 96,5 GPa Cast

Compressive Yield Strength 415 MPa

Ultimate Compressive Strength 830 MPa

Poisson's Ratio 0,15–0,21

Fatigue Strength 90 MPa 100,000,000 cycles, rotating beam

Shear Modulus 45 GPa

**Americium**

Bulk Modulus 45 GPa

**Curium**

Bulk Modulus 37 GPa

**Berkelium**

Bulk Modulus 52 GPa

**Californium**

Bulk Modulus 50 GPa

**Einsteinium**

Bulk Modulus 15 GPa Estimated

**Fermium**

Bulk Modulus 15 GPa Estimated

**Mineral Hardness (by Mohs) from**

*Г. В. Самсонов. Справочник "Свойства элементов".В 2 т. Москва, 1976 г.*

|  |  |
| --- | --- |
| Symbol | Mohs HM |
| Li | 0,6 |
| Be | 5,5 |
| B | 9,3 |
| Diamond (С) | 10 |
| Na | 0,5 |
| Mg | 2,5 |
| Al | 2,75 |
| Si | 6,5 |
| S | 2 |
| K | 0,4 |
| Ca | 1,75 |
| Ti | 6 |
| V | 7 |
| Cr | 8,5 |
| Symbol | Mohs HM |
| Mn | 6 |
| Fe | 4 |
| Co | 5 |
| Ni | 4 |
| Cu | 3 |
| Zn | 2,5 |
| Ga | 1,5 |
| Ge | 6 |
| As | 3,5 |
| Se | 2 |
| Rb | 0,3 |
| Sr | 1,5 |
| Zr | 5 |
| Nb | 6 |
| Mo | 5,5 |
| Ru | 6,5 |
| Rh | 6 |
| Pd | 4,75 |
| Ag | 2,5 |
| Cd | 2 |
| In | 1,2 |
| Sn | 1,5 |
| Sb | 3 |
| Te | 2,25 |
| Cs | 0,2 |
| Ba | 1,25 |
| La | 2,5 |
| Ce | 2,5 |
| Hf | 5,5 |
| Ta | 6,5 |
| W | 7,5 |
| Re | 7 |
| Os | 7 |
| Ir | 6,5 |
| Pt | 3,5 |
| Au | 2,5 |
| Tl | 1,2 |
| Pb | 1,5 |
| Bi | 2,25 |
| Th | 3 |
| U | 6 |

