THE ELEMENTS, HEAT, MASS, AND WEIGHT

The Elements — Symbols, Atomic Numbers and Weights, Melting Points

Name of Element	Symbol	Atomic Num.	Atomic Weight	Melting Point, °C	Name of Element	Symbol	Atomic Num.	Atomic Weight	Melting Point, °C
Actinium	Ac	89	227.028	1050	Neon	Ne	10	20.1179	−248.67
Aluminum	Al	13	26.9815	660.37	Neptunium	Np	93	237.048	640 ± 1
Americium	Am	95	(243)	994 ± 4	Nickel	Ni	28	58.69	1453
Antimony	Sb	51	121.75	630.74	Niobium	Nb	41	92.9064	2468 ± 10
Argon	A	18	39.948	−189.2	Nitrogen	N	7	14.0067	−209.86
Arsenic	As	33	74.9216	817[a]	Nobelium	No	102	(259)	…
Astatine	At	85	(210)	302	Osmium	Os	76	190.2	3045 ± 30
Barium	Ba	56	137.33	725	Oxygen	O	8	15.9994	−218.4
Berkelium	Bk	97	(247)	…	Palladium	Pd	46	106.42	1554
Beryllium	Be	4	9.01218	1278 ± 5	Phosphorus	P	15	30.9738	44.1
Bismuth	Bi	83	208.980	271.3	Platinum	Pt	78	195.08	1772
Boron	B	5	10.81	2079	Plutonium	Pu	94	(244)	641
Bromine	Br	35	79.904	−7.2	Polonium	Po	84	(209)	254
Cadmium	Cd	48	112.41	320.9	Potassium	K	19	39.0938	63.25
Calcium	Ca	20	40.08	839 ± 2	Praseodymium	Pr	59	140.908	931 ± 4
Californium	Cf	98	(251)	…	Promethium	Pm	61	(145)	1080[b]
Carbon	C	6	12.011	3652[c]	Protactinium	Pa	91	231.0359	1600
Cerium	Ce	58	140.12	798 ± 2	Radium	Ra	88	226.025	700
Cesium	Cs	55	132.9054	28.4 ± 0.01	Radon	Rn	86	(222)	−71
Chlorine	Cl	17	35.453	−100.98	Rhenium	Re	75	186.207	3180
Chromium	Cr	24	51.996	1857 ± 20	Rhodium	Rh	45	102.906	1965 ± 3
Cobalt	Co	27	58.9332	1495	Rubidium	Rb	37	85.4678	38.89
Copper	Cu	29	63.546	1083.4 ± 0.2	Ruthenium	Ru	44	101.07	2310
Curium	Cm	96	(247)	1340 ± 40	Samarium	Sm	62	150.36	1072 ± 5
Dysprosium	Dy	66	162.5	1409	Scandium	Sc	21	44.9559	1539
Einsteinium	Es	99	(252)	…	Selenium	Se	34	78.96	217
Erbium	Er	68	167.26	1522	Silicon	Si	14	28.0855	1410
Europium	Eu	63	151.96	822 ± 5	Silver	Ag	47	107.868	961.93
Fermium	Fm	100	(257)	…	Sodium	Na	11	22.9898	97.81 ± 0.03
Fluorine	F	9	18.9984	−219.62	Strontium	Sr	38	87.62	769
Francium	Fr	87	(223)	27[b]	Sulfur	S	16	32.06	112.8
Gadolinium	Gd	64	157.25	1311 ± 1	Tantalum	Ta	73	180.9479	2996
Gallium	Ga	31	69.72	29.78	Technetium	Tc	43	(98)	2172
Germanium	Ge	32	72.59	937.4	Tellurium	Te	52	127.60	449.5 ± 0.3
Gold	Au	79	196.967	1064.434	Terbium	Tb	65	158.925	1360 ± 4
Hafnium	Hf	72	178.49	2227 ± 20	Thallium	Tl	81	204.383	303.5
Helium	He	2	4.00260	−272.2[d]	Thorium	Th	90	232.038	1750
Holmium	Ho	67	164.930	1470	Thulium	Tm	69	168.934	1545 ± 15
Hydrogen	H	1	1.00794	−259.14	Tin	Sn	50	118.71	231.9681
Indium	In	49	114.82	156.61	Titanium	Ti	22	47.88	1660 ± 10
Iodine	I	53	126.905	113.5	Tungsten	W	74	183.85	3410 ± 20
Iridium	Ir	77	192.22	2410	Unnilhexium	Unh	106	(266)	…
Iron	Fe	26	55.847	1535	Unnilnonium	Unn	109	(266)	…
Krypton	Kr	36	83.80	−156.6	Unniloctium	Uno	108	(265)	…
Lanthanum	La	57	138.906	920 ± 5	Unnilpentium	Unp	105	(262)	…
Lawrencium	Lw	103	(260)	…	Unnilquadium	Unq	104	(261)	…
Lead	Pb	82	207.2	327.502	Unnilseptium	Uns	107	(261)	…
Lithium	Li	3	6.941	180.54	Uranium	U	92	238.029	1132 ± 0.8
Lutetium	Lu	71	174.967	1656 ± 5	Vanadium	V	23	50.9415	1890 ± 10
Magnesium	Mg	12	24.305	648.8 ± 0.5	Xenon	Xe	54	131.29	−111.9
Manganese	Mn	25	54.9380	1244 ± 2	Ytterbium	Yb	70	173.04	824 ± 5
Mendelevium	Md	101	(258)	…	Yttrium	Y	39	88.9059	1523 ± 8
Mercury	Hg	80	200.59	−38.87	Zinc	Zn	30	65.39	419.58
Molybdenum	Mo	42	95.94	2617	Zirconium	Zr	40	91.224	1852 ± 2
Neodymium	Nd	60	144.24	1010					

[a] At 28 atm.
[b] Approximate.
[c] Sublimates.
[d] At 26 atm.

Notes: Values in parentheses are atomic weights of the most stable known isotopes. Melting points at standard pressure except as noted.

Heat and Combustion Related Properties

Latent Heat.—When a body changes from the solid to the liquid state or from the liquid to the gaseous state, a certain amount of heat is used to accomplish this change. This heat does not raise the temperature of the body and is called latent heat. When the body changes again from the gaseous to the liquid, or from the liquid to the solid state, it gives out this quantity of heat. The *latent heat of fusion* is the heat supplied to a solid body at the melting point; this heat is absorbed by the body although its temperature remains nearly stationary during the whole operation of melting. The *latent heat of evaporation* is the heat that must be supplied to a liquid at the boiling point to transform the liquid into a vapor. The latent heat is generally given in British thermal units per pound. When it is said that the latent heat of evaporation of water is 966.6, this means that it takes 966.6 heat units to evaporate 1 pound of water after it has been raised to the boiling point, 212°F.

When a body changes from the solid to the gaseous state without passing through the liquid stage, as solid carbon dioxide does, the process is called *sublimation*.

Latent Heat of Fusion

Substance	Btu per Pound	Substance	Btu per Pound	Substance	Btu per Pound
Bismuth	22.75	Paraffine	63.27	Sulfur	16.86
Beeswax	76.14	Phosphorus	9.06	Tin	25.65
Cast iron, gray	41.40	Lead	10.00	Zinc	50.63
Cast iron, white	59.40	Silver	37.92	Ice	144.00

Latent Heat of Evaporation

Liquid	Btu per Pound	Liquid	Btu per Pound	Liquid	Btu per Pound
Alcohol, ethyl	371.0	Carbon Bisulfide	160.0	Turpentine	133.0
Alcohol, methyl	481.0	Ether	162.8	Water	966.6
Ammonia	529.0	Sulfur dioxide	164.0		

Boiling Points of Various Substances at Atmospheric Pressure

Substance	Boiling Point, °F	Substance	Boiling Point, °F	Substance	Boiling Point, °F
Aniline	363	Chloroform	140	Saturated brine	226
Alcohol	173	Ether	100	Sulfur	833
Ammonia	–28	Linseed oil	597	Sulfuric acid	590
Benzine	176	Mercury	676	Water, pure	212
Bromine	145	Napthaline	428	Water, sea	213.2
Carbon bisulfide	118	Nitric acid	248	Wood alcohol	150
		Oil of turpentine	315		

Specific Heat.—The specific heat of a substance is the ratio of the heat required to raise the temperature of a certain weight of the given substance 1°F to that required to raise the temperature of the same weight of water 1 degree. As the specific heat is not constant at all temperatures, it is generally assumed that it is determined by raising the temperature from 62 to 63°F. For most substances, however, specific heat is practically constant for temperatures up to 212°F.

Average Specific Heats (Btu/lb-°F) of Various Substance

Substance	Specific Heat	Substance	Specific Heat
Alcohol (absolute)	0.700	Kerosene	0.500
Alcohol (density 0.8)	0.622	Lead	0.031
Aluminum	0.214	Limestone	0.217
Antimony	0.051	Magnesia	0.222
Benzine	0.450	Marble	0.210
Brass	0.094	Masonry, brick	0.200
Brickwork	0.200	Mercury	0.033
Cadmium	0.057	Naphtha	0.310
Charcoal	0.200	Nickel	0.109
Chalk	0.215	Oil, machine	0.400
Coal	0.240	Oil, olive	0.350
Coke	0.203	Phosphorus	0.189
Copper, 32° to 212° F	0.094	Platinum	0.032
Copper, 32° to 572° F	0.101	Quartz	0.188
Corundum	0.198	Sand	0.195
Ether	0.503	Silica	0.191
Fusel oil	0.564	Silver	0.056
Glass	0.194	Soda	0.231
Gold	0.031	Steel, high carbon	0.117
Graphite	0.201	Steel, mild	0.116
Ice	0.504	Stone (generally)	0.200
Iron, cast	0.130	Sulfur	0.178
Iron, wrought, 32° to 212° F	0.110	Sulfuric acid	0.330
32° to 392° F	0.115	Tin	0.056
32° to 572° F	0.122	Turpentine	0.472
32° to 662° F	0.126	Water	1.000
Iron, at high temperatures:		Wood, fir	0.650
1382° to 1832° F	0.213	Wood, oak	0.570
1750° to 1840° F	0.218	Wood, pine	0.467
1920° to 2190° F	0.199	Zinc	0.095

Specific Heat of Gases (Btu/lb-°F)

Gas	Constant Pressure	Constant Volume	Gas	Constant Pressure	Constant Volume
Acetic acid	0.412	…	Chloroform	0.157	…
Air	0.238	0.168	Ethylene	0.404	0.332
Alcohol	0.453	0.399	Hydrogen	3.409	2.412
Ammonia	0.508	0.399	Nitrogen	0.244	0.173
Carbonic acid	0.217	0.171	Oxygen	0.217	0.155
Carbonic oxide	0.245	0.176	Steam	0.480	0.346
Chlorine	0.121	…			

Heat Loss from Uncovered Steam Pipes.—The loss of heat from a bare steam or hot-water pipe varies with the difference between the temperature inside the pipe and that of the surrounding air. The loss is 2.15 Btu per hour, per square foot of pipe surface, per degree F of temperature difference when the latter is 100 degrees; for a difference of 200 degrees, the loss is 2.66 Btu; for 300 degrees, 3.26 Btu; for 400 degrees, 4.03 Btu; for 500 degrees, 5.18 Btu. Thus, if the pipe area is 1.18 square feet per foot of length, and the temperature difference 300°F, the loss per hour per foot of length = $1.18 \times 300 \times 3.26 = 1154$ Btu.

Values of Thermal Conductivity (*k*) and of Conductance (*C*) of Common Building and Insulating Materials

Type of Material	Thickness, in.	*k* or *C*[a]	Type of Material	Thickness, in.	*k* or *C*[a]	Max. Temp., °F	Density, lb per cu. ft.	*k*[a]
BUILDING			BUILDING (*Continued*)					
Batt:	…	…	Siding:	…	…	…	…	…
Mineral Fiber	2–2¾	0.14	Metal[b]	Avg.	1.61	…	…	…
Mineral Fiber	3–3½	0.09	Wood, Med. Density	7/16	1.49	…	…	…
Mineral Fiber	3½–6½	0.05	Stone:	…	…	…	…	…
Mineral Fiber	6–7	0.04	Lime or Sand	1	12.50	…	…	…
Mineral Fiber	8½	0.03	Wall Tile:	…	…	…	…	…
Block:	…	…	Hollow Clay, 1-Cell	4	0.9	…	…	…
Cinder	4	0.90	Hollow Clay, 2-Cell	8	0.54	…	…	…
Cinder	8	0.58	Hollow Clay, 3-Cell	12	0.40	…	…	…
Cinder	12	0.53	Hollow Gypsum	Avg.	0.7	…	…	…
Block:	…	…	INSULATING					
Concrete	4	1.40	Blanket, Mineral Fiber:	…	…	…	…	…
Concrete	8	0.90	Felt	…	…	400	3 to 8	0.26
Concrete	12	0.78	Rock or Slag	…	…	1200	6 to 12	0.26[c]
Board:	…	…	Glass	…	…	350	0.65	0.33
Asbestos Cement	¼	16.5	Textile	…	…	350	0.65	0.31
Plaster	½	2.22	Blanket, Hairfelt	…	…	180	10	0.29
Plywood	¾	1.07	Board, Block and Pipe	…	…	…	…	…
Brick:	…	…	Insulation:	…	…	…	…	…
Common	1	5.0	Amosite	…	…	1500	15 to 18	0.32[c]
Face	1	9.0	Asbestos Paper	…	…	700	30	0.40[c]
Concrete (poured)	1	12.0	Glass or Slag (for Pipe)	…	…	350	3 to 4	0.23
Floor:	…	…	Glass or Slag (for Pipe)	…	…	1000	10 to 15	0.33[c]
Wood Subfloor	¾	1.06	Glass, Cellular	…	…	800	9	0.40
Hardwood Finish	¾	1.47	Magnesia (85%)	…	…	600	11 to 12	0.35[c]
Tile	Avg.	20.0	Mineral Fiber	…	…	100	15	0.29
Glass:	…	…	Polystyrene, Beaded	…	…	170	1	0.28
Architectural	…	10.00	Polystyrene, Rigid	…	…	170	1.8	0.25
Mortar:	…	…	Rubber, Rigid Foam	…	…	150	4.5	0.22
Cement	1	5.0	Wood Felt	…	…	180	20	0.31
Plaster:	…	…	Loose Fill:	…	…	…	…	…
Sand	⅜	13.30	Cellulose	…	…	…	2.5 to 3	0.27
Sand and Gypsum	½	11.10	Mineral Fiber	…	…	…	2 to 5	0.28
Stucco	1	5.0	Perlite	…	…	…	5 to 8	0.37
Roofing:	…	…	Silica Aerogel	…	…	…	7.6	0.17
Asphalt Roll	Avg.	6.50	Vermiculite	…	…	…	7 to 8.2	0.47
Shingle, asb. cem.	Avg.	4.76	Mineral Fiber Cement:	…	…	…	…	…
Shingle, asphalt	Avg.	2.27	Clay Binder	…	…	1800	24 to 30	0.49[c]
Shingle, wood	Avg.	1.06	Hydraulic Binder	…	…	1200	30 to 40	0.75[c]

[a] Units are in Btu/hr-ft^2-°F. Where thickness is given as 1 inch, the value given is thermal conductivity (*k*); for other thicknesses the value given is thermal conductance (*C*). All values are for a test mean temperature of 75°F, except those designated with [c], which are for 100°F.

[b] Over hollowback sheathing.

[c] Test mean temperature 100°F, see footnote [a].

Source: American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.: *Handbook of Fundamentals.*

Linear Expansion of Various Substances between 32 and 212°F
Expansion of volume = 3 × linear expansion

Substance	Linear Expansion for 1°F	Substance	Linear Expansion for 1°F
Brick	0.0000030	Masonry, brick from	0.0000026
Cement, Portland	0.0000060	to	0.0000050
Concrete	0.0000080	Plaster	0.0000092
Ebonite	0.0000428	Porcelain	0.0000020
Glass, thermometer	0.0000050	Quartz, from	0.0000043
Glass, hard	0.0000040	to	0.0000079
Granite	0.0000044	Slate	0.0000058
Marble, from	0.0000031	Sandstone	0.0000065
to	0.0000079	Wood, pine	0.0000028

Coefficients of Heat Transmission

Metal	Btu per Second	Metal	Btu per Second	Metal	Btu per Second
Aluminum	0.00203	German silver	0.00050	Steel, soft	0.00062
Antimony	0.00022	Iron	0.00089	Silver	0.00610
Brass, yellow	0.00142	Lead	0.00045	Tin	0.00084
Brass, red	0.00157	Mercury	0.00011	Zinc	0.00170
Copper	0.00404	Steel, hard	0.00034	…	…

Heat transmitted, in British thermal units, per second, through metal 1 inch thick, per square inch of surface, for a temperature difference of 1°F

Coefficients of Heat Radiation

Surface	Btu per Hour	Surface	Btu per Hour
Cast-iron, new	0.6480	Sawdust	0.7215
Cast-iron, rusted	0.6868	Sand, fine	0.7400
Copper, polished	0.0327	Silver, polished	0.0266
Glass	0.5948	Tin, polished	0.0439
Iron, ordinary	0.5662	Tinned iron, polished	0.0858
Iron, sheet-, polished	0.0920	Water	1.0853
Oil	1.4800	…	…

Heat radiated, in British thermal units, per square foot of surface per hour, for a temperature difference of 1° F

Freezing Mixtures

Mixture	Temperature Change, °F	
	From	To
Common salt ($NaCl$), 1 part; snow, 3 parts	32	±0
Common salt ($NaCl$), 1 part; snow, 1 part	32	−0.4
Calcium chloride ($CaCl_2$), 3 parts; snow, 2 parts	32	−27
Calcium chloride ($CaCl_2$), 2 parts; snow, 1 part	32	−44
Sal ammoniac (NH_4Cl), 5 parts; saltpeter (KNO_3), 5 parts; water, 16 parts	50	+10
Sal ammoniac (NH_4Cl), 1 part; saltpeter (KNO_3), 1 part; water, 1 part	46	−11
Ammonium nitrate (NH_4NO_3), 1 part; water, 1 part	50	+3
Potassium hydrate (KOH), 4 parts; snow, 3 parts	32	−35

Ignition Temperatures.—The following temperatures are required to ignite the different substances specified: Phosphorus, transparent, 120°F; bi sulfide of carbon, 300°F; gun cotton, 430°F; nitro-glycerine, 490°F; phosphorus, amorphous, 500°F; rifle powder, 550°F; charcoal, 660°F; dry pine wood, 800°F; dry oak wood, 900°F.

Typical Thermal Properties of Various Metals

Material and Alloy Designation[a]	Density, ρ lb/in³	Melting Point, °F		Conductivity, k, Btu/hr-ft-°F	Specific Heat, C, Btu/lb/°F	Coef. of Expansion, α µin./in.-°F
		solidus	liquidus			
Aluminum Alloys						
2011	0.102	995	1190	82.5	0.23	12.8
2017	0.101	995	1185	99.4	0.22	13.1
2024	0.100	995	1180	109.2	0.22	12.9
3003	0.099	1190	1210	111	0.22	12.9
5052	0.097	1100	1200	80	0.22	13.2
5086	0.096	1085	1185	73	0.23	13.2
6061	0.098	1080	1200	104	0.23	13.0
7075	0.101	890	1180	70	0.23	13.1
Copper-Base Alloys						
Manganese Bronze	0.302	1590	1630	61	0.09	11.8
C11000 (Electrolytic tough pitch)	0.321	1941	1981	226	0.09	9.8
C14500 (Free machining Cu)	0.323	1924	1967	205	0.09	9.9
C17200, C17300 (Beryllium Cu)	0.298	1590	1800	62	0.10	9.9
C18200 (Chromium Cu)	0.321	1958	1967	187	0.09	9.8
C18700 (Leaded Cu)	0.323	1750	1975	218	0.09	9.8
C22000 (Commercial bronze, 90%)	0.318	1870	1910	109	0.09	10.2
C23000 (Red brass, 85%)	0.316	1810	1880	92	0.09	10.4
C26000 (Cartridge brass, 70%)	0.313	1680	1750	70	0.09	11.1
C27000 (Yellow brass)	0.306	1660	1710	67	0.09	11.3
C28000 (Muntz metal, 60%)	0.303	1650	1660	71	0.09	11.6
C33000 (Low-leaded brass tube)	0.310	1660	1720	67	0.09	11.2
C35300 (High-leaded brass)	0.306	1630	1670	67	0.09	11.3
C35600 (Extra-high-leaded brass)	0.307	1630	1660	67	0.09	11.4
C36000 (Free machining brass)	0.307	1630	1650	67	0.09	11.4
C36500 (Leaded Muntz metal)	0.304	1630	1650	71	0.09	11.6
C46400 (Naval brass)	0.304	1630	1650	67	0.09	11.8
C51000 (Phosphor bronze, 5% A)	0.320	1750	1920	40	0.09	9.9
C54400 (Free cutting phos. bronze)	0.321	1700	1830	50	0.09	9.6
C62300 (Aluminum bronze, 9%)	0.276	1905	1915	31.4	0.09	9.0
C62400 (Aluminum bronze, 11%)	0.269	1880	1900	33.9	0.09	9.2
C63000 (Ni-Al bronze)	0.274	1895	1930	21.8	0.09	9.0
Nickel-Silver	0.314	1870	2030	17	0.09	9.0
Nickel-Base Alloys						
Nickel 200, 201, 205	0.321	2615	2635	43.3	0.11	8.5
Hastelloy C-22	0.314	2475	2550	7.5	0.10	6.9
Hastelloy C-276	0.321	2415	2500	7.5	0.10	6.2
Inconel 718	0.296	2300	2437	6.5	0.10	7.2
Monel	0.305	2370	2460	10	0.10	8.7
Monel 400	0.319	2370	2460	12.6	0.10	7.7
Monel K500	0.306	2400	2460	10.1	0.10	7.6
Monel R405	0.319	2370	2460	10.1	0.10	7.6

Typical Thermal Properties of Various Metals *(Continued)*

Material and Alloy Designation[a]	Density, ρ lb/in^3	Melting Point, °F		Conductivity, *k*, Btu/hr-ft-°F	Specific Heat, *C*, Btu/lb/°F	Coef. of Expansion, α μin./in.-°F
		solidus	liquidus			
Stainless Steels						
S30100	0.290	2550	2590	9.4	0.12	9.4
S30200, S30300, S30323	0.290	2550	2590	9.4	0.12	9.6
S30215	0.290	2500	2550	9.2	0.12	9.0
S30400, S30500	0.290	2550	2650	9.4	0.12	9.6
S30430	0.290	2550	2650	6.5	0.12	9.6
S30800	0.290	2550	2650	8.8	0.12	9.6
S30900, S30908	0.290	2550	2650	9.0	0.12	8.3
S31000, S31008	0.290	2550	2650	8.2	0.12	8.8
S31600, S31700	0.290	2500	2550	9.4	0.12	8.8
S31703	0.290	2500	2550	8.3	0.12	9.2
S32100	0.290	2550	2600	9.3	0.12	9.2
S34700	0.290	2550	2650	9.3	0.12	9.2
S34800	0.290	2550	2650	9.3	0.12	9.3
S38400	0.290	2550	2650	9.4	0.12	9.6
S40300, S41000, S41600, S41623	0.280	2700	2790	14.4	0.11	5.5
S40500	0.280	2700	2790	15.6	0.12	6.0
S41400	0.280	2600	2700	14.4	0.11	5.8
S42000, S42020	0.280	2650	2750	14.4	0.11	5.7
S42200	0.280	2675	2700	13.8	0.11	6.2
S42900	0.280	2650	2750	14.8	0.11	5.7
S43000, S43020, S43023	0.280	2600	2750	15.1	0.11	5.8
S43600	0.280	2600	2750	13.8	0.11	5.2
S44002, S44004	0.280	2500	2700	14.0	0.11	5.7
S44003	0.280	2500	2750	14.0	0.11	5.6
S44600	0.270	2600	2750	12.1	0.12	5.8
S50100, S50200	0.280	2700	2800	21.2	0.11	6.2
Cast Iron and Steel						
Malleable Iron, A220 (50005, 60004, 80002)	0.265	liquidus approximately, 2100 to 2200, depending on composition		29.5	0.12	7.5
Grey Cast Iron	0.25			28.0	0.25	5.8
Ductile Iron, A536 (120–90–02)	0.25				0.16	5.9–6.2
Ductile Iron, A536 (100–70–03)	0.25			20.0	0.16	5.9–6.2
Ductile Iron, A536 (80–55–06)	0.25			18.0	0.15	5.9–6.2
Ductile Iron, A536 (65–45–120)	0.25			20.8	0.15	5.9–6.2
Ductile Iron, A536 (60–40–18)	0.25				0.12	5.9–6.2
Cast Steel, 3%C	0.25	liquidus, 2640		28.0	0.12	7.0
Titanium Alloys						
Commercially Pure	0.163	3000	3040	9.0	0.12	5.1
Ti-5Al-2.5Sn	0.162	2820	3000	4.5	0.13	5.3
Ti-8Mn	0.171	2730	2970	6.3	0.19	6.0

[a] Alloy designations correspond to the AluminumAssociation numbers for aluminum alloys and to the unified numbering system (UNS) for copper and stainless steel alloys. A220 and A536 are ASTM specified irons.

Properties of Mass and Weight

Specific Gravity.—Specific gravity is a number indicating how many times a certain volume of a material is heavier than an equal volume of water. The density of water differs slightly at different temperatures, so the usual custom is to make comparisons on the basis that the water has a temperature of 62°F. The weight of 1 cubic inch of pure water at 62°F is 0.0361 pound. If the specific gravity of any material is known, the weight of a cubic inch of the material, therefore, can be found by multiplying its specific gravity by 0.0361.

Example: The specific gravity of cast iron is 7.2. Find the weight of 5 cubic inches of cast iron.

$$7.2 \times 0.0361 \times 5 = 1.2996 \text{ pounds}$$

To find the weight per cubic foot of a material, multiply the specific gravity by 62.355.

If the weight of a cubic inch of a material is known, the specific gravity is found by dividing the weight per cubic inch by 0.0361.

Example: The weight of a cubic inch of gold is 0.697 pound. Find the specific gravity.

$$0.697 \div 0.0361 = 19.31$$

If the weight per cubic foot of a material is known, the specific gravity is found by multiplying this weight by 0.01604.

Average Specific Gravity of Various Substances

Substance	Specific Gravity	Weight lb/ft³	Substance	Specific Gravity	Weight lb/ft³
ABS	1.05	66	Lead	11.4	711
Acrylic	1.19	74	Limestone	2.6	162
Aluminum bronze	7.8	486	Marble	2.7	168
Aluminum, cast	2.6	160	Masonry	2.4	150
Aluminum, wrought	2.7	167	Mercury	13.56	845.3
Asbestos	2.4	150	Mica	2.8	175
Asphaltum	1.4	87	Mortar	1.5	94
Borax	1.8	112	Nickel, cast	8.3	517
Brick, common	1.8	112	Nickel, rolled	8.7	542
Brick, fire	2.3	143	Nylon 6, Cast	1.16	73
Brick, hard	2.0	125	PTFE	2.19	137
Brick, pressed	2.2	137	Phosphorus	1.8	112
Brickwork, in cement	1.8	112	Plaster of Paris	1.8	112
Brickwork, in mortar	1.6	100	Platinum	21.5	1342
CPVC	1.55	97	Polycarbonate	1.19	74
Cement, Portland (set)	3.1	193	Polyethylene	0.97	60
Chalk	2.3	143	Polypropylene	0.91	57
Charcoal	0.4	25	Polyurethane	1.05	66
Coal, anthracite	1.5	94	Quartz	2.6	162
Coal, bituminous	1.3	81	Salt, common	…	48
Concrete	2.2	137	Sand, dry	…	100
Earth, loose	…	75	Sand, wet	…	125
Earth, rammed	…	100	Sandstone	2.3	143
Emery	4.0	249	Silver	10.5	656
Glass	2.6	162	Slate	2.8	175
Glass, crushed	…	74	Soapstone	2.7	168
Gold, 22 carat fine	17.5	1091	Steel	7.9	491
Gold, pure	19.3	1204	Sulfur	2.0	125
Granite	2.7	168	Tar, bituminous	1.2	75
Gravel	…	109	Tile	1.8	112
Gypsum	2.4	150	Trap rock	3.0	187
Ice	0.9	56	Water at 62°F	1.0	62.355
Iron, cast	7.2	447	White metal	7.3	457
Iron, wrought	7.7	479	Zinc, cast	6.9	429
Iron slag	2.7	168	Zinc, sheet	7.2	450

The weight per cubic foot is calculated on the basis of the specific gravity except for those substances that occur in bulk, heaped, or loose form. In these instances, only the weights per cubic foot are given because the voids present in representative samples make the values of the specific gravities inaccurate.

Specific Gravity of Gases.— The specific gravity of gases is the number that indicates their weight in comparison with that of an equal volume of air. The specific gravity of air is 1, and the comparison is made at 32°F.

Specific Gravity of Gases At 32°F

Gas	Sp. Gr.	Gas	Sp. Gr.	Gas	Sp. Gr.
Air	1.000	Ether vapor	2.586	Marsh gas	0.555
Acetylene	0.920	Ethylene	0.967	Nitrogen	0.971
Alcohol vapor	1.601	Hydrofluoric acid	2.370	Nitric oxide	1.039
Ammonia	0.592	Hydrochloric acid	1.261	Nitrous oxide	1.527
Carbon dioxide	1.520	Hydrogen	0.069	Oxygen	1.106
Carbon monoxide	0.967	Illuminating gas	0.400	Sulfur dioxide	2.250
Chlorine	2.423	Mercury vapor	6.940	Water vapor	0.623

1 cubic foot of air at 32°F and atmospheric pressure weighs 0.0807 pound.

Specific Gravity of Liquids.— The specific gravity of liquids is the number that indicates how much a certain volume of the liquid weighs compared with an equal volume of water, the same as with solid bodies. The density of liquid is often expressed in degrees on the hydrometer, an instrument for determining the density of liquids, provided with graduations made to an arbitrary scale. The hydrometer consists of a glass tube with a bulb at one end containing air, and arranged with a weight at the bottom so as to float in an upright position in the liquid, the density of which is to be measured. The depth to which the hydrometer sinks in the liquid is read off on the graduated scale. The most commonly used hydrometer is the Baumé. The value of the degrees of the Baumé scale differs according to whether the liquid is heavier or lighter than water. The specific gravity for liquids heavier than water equals 145 ÷ (145 − degrees Baumé). For liquids lighter than water, the specific gravity equals 140 ÷ (130 + degrees Baumé).

Specific Gravity of Liquids

Liquid	Sp. Gr.	Liquid	Sp. Gr.	Liquid	Sp. Gr.
Acetic acid	1.06	Fluoric acid	1.50	Petroleum oil	0.82
Alcohol, commercial	0.83	Gasoline	0.70	Phosphoric acid	1.78
Alcohol, pure	0.79	Kerosene	0.80	Rape oil	0.92
Ammonia	0.89	Linseed oil	0.94	sulfuric acid	1.84
Benzine	0.69	Mineral oil	0.92	Tar	1.00
Bromine	2.97	Muriatic acid	1.20	Turpentine oil	0.87
Carbolic acid	0.96	Naphtha	0.76	Vinegar	1.08
Carbon di sulfide	1.26	Nitric acid	1.50	Water	1.00
Cotton-seed oil	0.93	Olive oil	0.92	Water, sea	1.03
Ether, sulfuric	0.72	Palm oil	0.97	Whale oil	0.92

Degrees on Baumé's Hydrometer Converted to Specific Gravity

Deg. Baumé	Specific Gravity		Deg. Baumé	Specific Gravity		Deg. Baumé	Specific Gravity	
	Liquids Heavier than Water	Liquids Lighter than Water		Liquids Heavier than Water	Liquids Lighter than Water		Liquids Heavier than Water	Liquids Lighter than Water
0	1.000	…	27	1.229	0.892	54	1.593	0.761
1	1.007	…	28	1.239	0.886	55	1.611	0.757
2	1.014	…	29	1.250	0.881	56	1.629	0.753
3	1.021	…	30	1.261	0.875	57	1.648	0.749
4	1.028	…	31	1.272	0.870	58	1.667	0.745
5	1.036	…	32	1.283	0.864	59	1.686	0.741
6	1.043	…	33	1.295	0.859	60	1.706	0.737
7	1.051	…	34	1.306	0.854	61	1.726	0.733
8	1.058	…	35	1.318	0.849	62	1.747	0.729
9	1.066	…	36	1.330	0.843	63	1.768	0.725
10	1.074	1.000	37	1.343	0.838	64	1.790	0.721
11	1.082	0.993	38	1.355	0.833	65	1.813	0.718
12	1.090	0.986	39	1.368	0.828	66	1.836	0.714
13	1.099	0.979	40	1.381	0.824	67	1.859	0.710
14	1.107	0.972	41	1.394	0.819	68	1.883	0.707
15	1.115	0.966	42	1.408	0.814	69	1.908	0.704
16	1.124	0.959	43	1.422	0.809	70	1.933	0.700
17	1.133	0.952	44	1.436	0.805	71	1.959	0.696
18	1.142	0.946	45	1.450	0.800	72	1.986	0.693
19	1.151	0.940	46	1.465	0.796	73	2.014	0.689
20	1.160	0.933	47	1.480	0.791	74	2.042	0.686
21	1.169	0.927	48	1.495	0.787	75	2.071	0.683
22	1.179	0.921	49	1.510	0.782	76	2.101	0.679
23	1.189	0.915	50	1.526	0.778	77	2.132	0.676
24	1.198	0.909	51	1.542	0.773	78	2.164	0.673
25	1.208	0.903	52	1.559	0.769	79	2.197	0.669
26	1.219	0.897	53	1.576	0.765	80	2.230	0.666

Average Weights and Volumes of Fuels.—The average weight of a bushel of charcoal is 20 pounds; of a bushel of coke, 40 pounds; of a bushel of anthracite coal, 67 pounds; and of a bushel of bituminous coal, 60 pounds.

Anthracite coal, 1 cubic foot = 55 to 65 pounds.

Anthracite coal, 1 ton (2240 pounds) = 34 to 41 cubic feet.

Bituminous coal, 1 cubic foot = 50 to 55 pounds.

Bituminous coal, 1 ton (2240 pounds) = 41 to 45 cubic feet.

Charcoal, 1 cubic foot = 18 to 18.5 pounds.

Charcoal, 1 ton (2240 pounds) = 120 to 124 cubic feet.

Coke, 1 cubic foot = 28 pounds.

Coke, 1 ton (2240 pounds) = 80 cubic feet.

Weight of Wood.—The weight of seasoned wood per cord is approximately as follows, assuming about 70 cubic feet of *solid wood* per cord: beech, 3300 pounds; chestnut, 2600 pounds; elm, 2900 pounds; maple, 3100 pounds; poplar, 2200 pounds; white pine, 2200 pounds; red oak, 3300 pounds; white oak, 3500 pounds.

Weight per Foot of Wood, Board Measure.—The following is the weight in pounds of various kinds of woods, commercially known as dry timber, per foot board measure: white oak, 4.16; white pine, 1.98; Douglas fir, 2.65; short-leaf yellow pine, 2.65; red pine, 2.60; hemlock, 2.08; spruce, 2.08; cypress, 2.39; cedar, 1.93; chestnut, 3.43; Georgia yellow pine, 3.17; California spruce, 2.08.

How to Estimate the Weight of Natural Piles.—To calculate the upper and lower limits of the weight of a substance piled naturally on a circular plate, so as to form a cone of material, use the equation:

$$W = MD^3 \quad (1)$$

where W = weight, lb; D = diameter of plate, ft. (Fig. 1a); and, M = materials factor, whose upper and lower limits are given in Table 1.

For a rectangular plate, calculate the weight of material piled naturally by means of the following equation:

$$W = MRA^3 \quad (2)$$

where A and B = the length and width in ft., respectively, of the rectangular plate in Fig. 1b, with $B \le A$; and, R = is a rectangular factor given in Table 2 as a function of the ratio B/A.

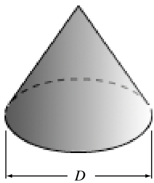

Fig. 1a. Conical Pile

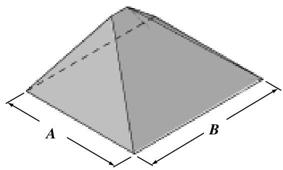

Fig. 1b. Rectangular Pile

Example 1: Find the upper and lower limits of the weight of dry ashes piled naturally on a plate 10 ft. in diameter.

Using Equation (1), $M = 4.58$ from Table 1, the lower limit $W = 4.58 \times 10^3 = 4{,}580$ lb. For $M = 5.89$, the upper limit $W = 5.89 \times 10^3 = 5{,}890$ lb.

Example 2: What weight of dry ashes rests on a rectangular plate 10 ft. by 5 ft.?

For $B/A = 5/10 = 0.5$, $R = 0.39789$ from Table 2. Using Equation (2), for $M = 4.58$, the lower limit $W = 4.58 \times 0.39789 \times 10^3 = 1{,}822$ lb. For $M = 5.89$, the upper limit $W = 5.89 \times 0.39789 \times 10^3 = 2{,}344$lb.

Table 1. Limits of Factor *M* for Various Materials

Material	Factor *M*	Material	Factor *M*	Material	Factor *M*
Aluminum chips	0.92-196	Cast-iron chips	17.02-26.18	Potassium carbonate	3.85-6.68
Aluminum silicate	3.70-6.41	Cinders, coal	3.02-5.24	Potassium sulfate	5.50-6.28
Ammonium chloride	3.93-6.81	Coal, anthracite, chestnut	2.43	Saltpeter	6.05-10.47
Asbestos, shred	2.62-3.27	Coal, ground	2.90	Salt rock, crushed	4.58
Ashes, dry	4.58-5.89	Coke, pulverized	2.21	Sand, very fine	7.36-9.00
Ashes, damp	6.24-7.80	Copper oxide, powdered	20.87	Sawdust, dry	0.95-2.85
Asphalt, crushed	3.4-5.89	Cork, granulated	1.57-1.96	Sodium nitrate	3.96-4.66
Bakelite, powdered	3.93-5.24	Dicalcium phosphate	5.63	Sodium sulfite	10.54
Baking powder	3.10-5.37	Fluorspar	10.73-14.40	Sodium sulfate	6.92
Barium carbonate	9.42	Graphite, flake	3.02-5.24	Sulfur	4.50-6.95
Boric acid	4.16-7.20	Lead silicate, granulated	25.26	Talcum powder	4.37-5.90
Bronze, chips	3.93-6.54	Lead sulfate, pulverized	24.09	Tin oxide, ground	9.17
Calcium lactate	3.40-3.80	Limestone, pulverized	8.84-10.02	Trisodium phosphate	4.53-7.85
Calcium oxide	3.30	Magnesium chloride	4.32	Wood chips, fir	2.49-2.88
Carbon, ground	2.51	Manganese sulfate	5.29-9.16	Zinc sulfate	8.85-11.12
Casein	2.72-4.71	Mica, ground	1.24-1.43		

Table 2. Factor *R* as a function of *B*/*A* ($B \leq A$)

B/*A*	*R*	*B*/*A*	*R*	*B*/*A*	*R*	*B*/*A*	*R*
0.01	0.00019	0.26	0.11792	0.51	0.41231	0.76	0.82367
0.02	0.00076	0.27	0.12670	0.52	0.42691	0.77	0.84172
0.03	0.00170	0.28	0.13576	0.53	0.44170	0.78	0.85985
0.04	0.00302	0.29	0.14509	0.54	0.45667	0.79	0.87807
0.05	0.00470	0.30	0.15470	0.55	0.47182	0.80	0.89636
0.06	0.00674	0.31	0.16457	0.56	0.48713	0.81	0.91473
0.07	0.00914	0.32	0.17471	0.57	0.50262	0.82	0.93318
0.08	0.01190	0.33	0.18511	0.58	0.51826	0.83	0.95169
0.09	0.01501	0.34	0.19576	0.59	0.53407	0.84	0.97027
0.10	0.01846	0.35	0.20666	0.60	0.55004	0.85	0.98891
0.11	0.02226	0.36	0.21782	0.61	0.56616	0.86	1.00761
0.12	0.02640	0.37	0.22921	0.62	0.58243	0.87	1.02636
0.13	0.03088	0.38	0.24085	0.63	0.59884	0.88	1.04516
0.14	0.03569	0.39	0.25273	0.64	0.61539	0.89	1.06400
0.15	0.04082	0.40	0.26483	0.65	0.63208	0.90	1.08289
0.16	0.04628	0.41	0.27717	0.66	0.64891	0.91	1.10182
0.17	0.05207	0.42	0.28973	0.67	0.66586	0.92	1.12078
0.18	0.05817	0.43	0.30252	0.68	0.68295	0.93	1.13977
0.19	0.06458	0.44	0.31552	0.69	0.70015	0.94	1.15879
0.20	0.07130	0.45	0.32873	0.70	0.71747	0.95	1.17783
0.21	0.07833	0.46	0.34216	0.71	0.73491	0.96	1.19689
0.22	0.08566	0.47	0.35579	0.72	0.75245	0.97	1.21596
0.23	0.09329	0.48	0.36963	0.73	0.77011	0.98	1.23505
0.24	0.10121	0.49	0.38366	0.74	0.78787	0.99	1.25414
0.25	0.10942	0.50	0.39789	0.75	0.80572	1.00	1.27324