2e. Elastic Constants, Hardness, Strength, Elastic Limits, and Diffusion Coefficients of Solids

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2e-1. Introduction. For the fundamental ideas connected with elasticity and for the definition of the elastic constants see Sec. 2a-6. For other definitions see Sec. 2e-3. The symbols and abbreviations used in this section are presented below.

E	Young's modulus
G	modulus of rigidity
σ	Poisson's ratio
ρ	density
C_{ij}	elastic constant (cf. Sec. 2a-6)
S_{ij}	elastic coefficient (cf. Sec. 2a-6)
T.S.	tensile strength
Y.S.	yield strength
Y.P.	yield point
S.S.	shear strength
El.	elongation
R.A.	reduction in area
Bhn	Brinell hardness number
R	Rockwell hardness number (often used with subscripts)
Vdh, Vhn	Vickers hardness number
D	diffusion coefficient
v	specific volume
p	pressure

2e-2. Elastic Constants and Coefficients of Crystals. Tables 2e-1 through 2e-6 contain tabulations of the elastic constants C_{ij} and coefficients S_{ij} of cubic, hexagonal, tetragonal, trigonal, orthorhombic, and monoclinic crystals (cf. Sec. 9a for X-ray crystallographic data). All temperatures are room temperatures unless otherwise specified. However, the original sources often contain values for a wide range of temperatures.

The two electrical boundary conditions for piezoelectric crystals are as follows: $D = 0$ denotes an electric field, generated piezoelectrically, parallel to the direction of wave propagation; $E = 0$ denotes a field perpendicular to this direction. Boundary

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conditions are given only for those materials for which a change in boundary conditions produces a substantial change in one or more measured values.

References for these tables will be found immediately following Table 2e-6. References 1, 2, and 3 are published compilations from which the original sources can be obtained as well as references for values differing slightly from those given in these tables. In those cases in which two references are given, the first is for C_{ij} and the second for S_{ij}.

2e-3. Elastic Constants, Hardness, Strength, and Elastic Limits of Polycrystalline Solids. Tables 2e-7 through 2e-16 contain data on the Young's modulus, modulus of rigidity, hardness, etc., of various solids, metals, and alloys. The elastic constants, tensile strength, yield strength, shear strength, and all other quantities having the dimensions of stress are expressed in dynes per square centimeter. The definitions of these and other tabulated quantities are given in the following list.

1. *Tensile Strength.*[1] "The maximum tensile stress which a material is capable of developing."

Note: In practice, it is considered to be the maximum stress developed by a specimen representing the material in a tension test carried to rupture, under definite prescribed conditions. Tensile strength is calculated from the maximum load P carried during a tension test and the original cross-sectional area of the specimen A_0 from the formula

$$\text{Tensile strength} = \frac{P}{A_0}$$

2. *Yield Strength.*[1] "The stress at which a material exhibits a specified permanent set."

The yield strength is conventionally determined in either of two ways. In the first method, a specimen of the material is repeatedly loaded and unloaded with the load being increased at each cycle, the process being continued until a specified permanent set is obtained after one of the unloadings. The stress which produces this specified permanent set is called the yield strength.

In the second method, known as the offset method, a load-elongation curve is determined experimentally, the elongation being measured in units of extension per unit length of the undeformed specimen. A straight line is then drawn having a slope equal to the initial slope of the load-elongation curve and an intercept on the elongation axis equal to the specified offset, which is usually given in units of per cent elongation. The yield strength is taken to be that load defined by the interaction of the added straight line with the load-elongation curve.

Further discussion of yield strength can be found in ASTM E6-36.

3. *Yield Point.*[2] The stress at which a marked increase in deformation takes place without increase in the load.

4. *Shear Strength.*[3] "The stress, usually expressed in pounds per square inch, required to produce fracture when impressed perpendicularly upon the cross-section of a material."

5. *Elongation.*[4] "In tensile testing the elongation of a specimen is the increase in gage length, after rupture, referred to the original gage length. It is reported as percentage elongation."

6. *Reduction in Area.*[4] "In tensile testing the reduction in area of a specimen is the ratio of the difference between the original cross-sectional area of the specimen and the cross-sectional area after rupture, to the original cross-sectional area. It is reported as the percentage reduction of area."

[1] Standard Definitions of Terms Relating to Methods of Testing, ASTM E6-36.
[2] "Metals Handbook," 1948 ed., American Society for Metals.
[3] J. G. Henderson, "Metallurgical Dictionary."
[4] *Natl. Bur. Standards (U.S.) Circ.* C447.

TABLE 2e-1. ELASTIC CONSTANTS AND COEFFICIENTS OF CUBIC CRYSTALS
(C_{ij} in units of 10^{11} dynes/cm^2; S_{ij} in units of 10^{-13} cm^2/dyne)

Material	C_{11}	C_{12}	C_{44}	S_{11}	S_{12}	S_{44}	Ref.
Ag (silver)	12.40	9.34	4.61	22.9	−9.83	21.7	2
Ag, 25% Au	......	......	......	20.7	−8.91	20.5	4
Ag, 50% Au	......	......	......	19.7	−8.52	19.7	4
Ag, 75% Au	......	......	......	20.5	−9.09	20.6	4
AgBr	5.63	3.3	0.720	31.3	−11.7	139	2
AgCl	6.01	3.62	0.625	30.4	−11.4	160	2
Ag, 1.34% Cd	12.28	9.25	4.61	23.07	−9.91	21.69	5
Ag, 1.92% Cd	12.16	9.13	4.59	23.10	−9.91	21.77	5
Ag, 8.36% In	11.66	8.90	4.50	25.30	−10.95	22.20	5
Ag, 3.07% Mg	11.98	8.98	4.60	23.37	−10.01	21.74	5
Ag, 7.33% Mg	11.59	8.66	4.52	23.94	−10.24	22.10	5
Ag, 6.22% Pd	12.77	9.58	4.81	21.93	−9.40	20.79	5
Ag, 3.17% Sn	12.10	9.22	4.58	24.29	−10.51	21.83	5
Ag, 2.40% Zn	12.09	9.16	4.58	23.89	−10.30	21.85	5
Ag, 3.53% Zn	12.30	9.33	4.61	23.54	−10.16	21.68	5
Alum	2.56	1.07	0.85	52	−15	118	1
Aluminum	11.2	6.6	2.79	15.7	−5.8	35.9	1
Al, 5% Cu	......	......	......	15	−6.9	37	6
Ammonium alum	2.50	1.06	0.80	53.5	−15.9	125	7, 3
Ammonium bromide	2.96	0.59	0.53	36.2	−6.0	189	1
Ammonium chloride	3.90	0.72	0.68	27.2	−4.2	147	1
Au (gold)	18.6	15.7	4.20	23.3	−10.65	23.8	2
Barium nitrate	6.04	1.86	1.22	19.4	−4.6	82.0	1
CaF_2 (fluorspar)	16.44	5.02	3.47	7.10	−1.66	28.8	2
Chromite	32.3	14.4	11.7	4.27	−1.31	8.56	2
Chromium alum	......	......	......	54.2	−15.3	130	3
Cobalt zinc ferrite	26.6	15.3	7.8	6.49	−2.37	12.8	1
Copper	16.8	12.1	7.54	15.0	−6.3	13.26	1
Cu_3Au	19.07	13.83	6.63	13.4	−5.65	15.1	2
Cu, 4.1% Zn (α-brass)	16.33	11.77	7.44	......	......	......	8
Cu, 9.1% Zn (α-brass)	15.71	11.37	7.23	......	......	......	8
Cu, 17.1% Zn (α-brass)	14.99	10.97	7.15	......	......	......	8
Cu, 22.7% Zn (α-brass)	14.47	10.71	7.13	......	......	......	8
Cu, 47% Zn (α-brass)	15.22	11.62	7.19	......	......	......	9
Cu, 44.9% Zn (β-brass)	11.9	10.2	7.44	41.05	−19.0	13.4	2
Cu, 48.3% Zn (β-brass)	12.91	10.97	8.24	35.3	−16.2	12.2	2
Cu, 48.9% Zn (β-brass)	12.79	10.91	8.22	36.4	−16.8	12.2	1
Cu, 4.81% Al	16.58	12.16	7.49	15.9	−6.73	13.35	10
Cu, 9.98% Al	15.95	11.76	7.66	16.75	−7.11	13.05	10
Cu, 1.58% Ga	16.50	11.92	7.43	15.38	−6.45	13.46	10
Cu, 4.15% Ga	16.52	12.10	7.41	15.91	−6.73	13.50	10
Cu, 1.03% Ge	16.66	12.10	7.50	15.44	−6.50	13.33	10
Cu, 1.71% Ge	16.31	11.82	7.50	15.72	−6.60	13.33	10
Cu, 4.17% Si	16.78	12.42	7.48	16.10	−6.85	13.37	10
Cu, 5.16% Si	16.08	11.88	7.49	16.71	−7.10	13.35	10
Cu, 7.69% Si	16.58	12.64	7.41	17.72	−7.66	13.50	10
Cu, 4.59% Zn	16.34	11.92	7.42	15.91	−6.71	13.48	10

TABLE 2e-1. ELASTIC CONSTANTS AND COEFFICIENTS OF CUBIC CRYSTALS (*Continued*)

Material	C_{11}	C_{12}	C_{44}	S_{11}	S_{12}	S_{44}	Ref.
Cu, 28% Zn	......	......	......	19.4	−8.4	13.9	11
Diamond	107.6	12.50	57.58	0.953	−0.099	1.74	12
Diamond	95	39	43	1.38	−0.40	2.3	13
Fe	23.7	14.1	11.6	7.72	−2.85	9.02	9, 14
Garnet 21.8% FeO	19.7	9.0	5.7	7.11	−2.2	17.5	15
Garnet 22.7% FeO	19.2	9.9	5.9	8.02	−2.7	16.9	15
Garnet 23.0% FeO	22.2	10.4	7.0	6.42	−2.1	14.3	15
Garnet 23.6% FeO	21.0	10.3	6.7	7.03	−2.3	14.9	15
Garnet 26.2% FeO	22.6	12.6	6.2	7.36	−2.6	16.1	15
Garnet 28.7% FeO	27.3	15.7	6.8	6.32	−2.3	14.7	15
Garnet 33.5% FeO	32.7	12.4	8.9	3.87	−1.1	11.2	15
Fe_3O_4 (magnetite)	27.3	10.6	9.7	4.7	−1.31	10.3	2
FeS_2 (pyrite)	36.2	−4.4	10.4	2.85	0.39	9.6	2
GaAs	1.192	0.599	0.538	126.4	−42.34	186	2
GaSb	8.85	4.04	4.33	15.8	−4.96	23.1	2
Germanium	12.89	4.83	6.71	9.78	−2.66	14.90	2
Hexamethylene tetramine	1.5	0.3	0.7	70	−12	140	1
Lead nitrate	4.56	3.09	1.37	48.5	−19.6	73.0	1
Indium antimonide	6.72	3.67	3.02	24.2	−8.55	33.1	2
Potassium alum	2.54	1.07	0.84	52.5	−15.6	119	2
K (potassium)	0.459	0.372	0.263	833	−370	380	9, 16
KBr	3.46	0.58	0.505	30.4	−4.35	198	2
KCl	3.98	0.62	0.625	26.2	−3.5	160	2
KF	6.58	1.49	1.28	......	....	.....	17
KI	2.67	0.43	0.421	39.2	−5.4	238	2
Li (195°K)	1.320	1.102	0.960	316.4	−144	104	18
LiBr	3.94	1.88	1.91	......	....	.....	17
LiCl	4.94	2.26	2.49	......	....	.....	17
LiF	11.12	4.20	6.28	11.35	−3.1	15.9	2
LiI	2.85	1.40	1.35	......	....	.....	17
MgO	28.6	8.7	14.8	4.08	−0.95	6.76	2
Magnetite	27.5	10.4	9.55	4.59	−1.26	10.47	1
Molybdenum	46	17.6	11.0	2.8	−0.78	9.1	2
Na (sodium)	0.945	0.779	0.618	420	−190	162	2
NaBr	3.87	0.97	0.97	28.7	−5.8	103	2
$NaBrO_3$	5.73	1.76	1.52	20.4	−4.8	65.7	2
NaCl	4.87	1.24	1.26	22.9	−4.65	79.4	2
$NaClO_3$	4.99	1.41	1.17	22.9	−5.05	85.4	2
NaF	9.71	2.43	2.80	......	....	.....	17
NaI	3.035	0.90	0.72	......	....	.....	17
Ammonium alum	2.50	1.06	0.8	53.5	−15.9	125	2
NH_4Br	2.96	0.59	0.53	36.2	−6.0	189	2
NH_4Cl	3.90	0.72	0.68	27.2	−4.2	147	2
Nickel	24.65	14.73	12.47	7.34	−2.74	8.02	2
Palladium	22.71	17.60	7.173	......	....	.....	19
Pb (lead)	5.03	3.93	1.40	63.2	−27.7	71.4	20
Pb	4.66	3.92	1.44	92.8	−42.4	69.4	2
PbS (galena)	10.2	3.8	2.5	12	−3	40	1

TABLE 2e-1. ELASTIC CONSTANTS AND COEFFICIENTS OF CUBIC CRYSTALS (*Continued*)

Material	C_{11}	C_{12}	C_{44}	S_{11}	S_{12}	S_{44}	Ref.
PbS	12.70	2.98	2.48	8.7	−1.64	40.3	1
RbBr	3.185	0.48	0.385	......	......	......	17
RbCl	3.645	0.61	0.475	......	......	......	17
RbF	5.7	1.25	0.91	......	......	......	17
RbI	2.585	0.375	0.281	......	......	......	17
Silicon	16.57	6.39	7.96	7.68	−2.14	12.56	2
Strontium nitrate	4.73	2.18	1.46	29.8	−9.4	68.5	1
Thallium bromide	3.78	1.48	0.756	33.9	−9.5	132	2
Thallium chloride	4.01	1.53	0.760	31.6	−8.7	132	2
Thallium alum	......	......	......	49.0	−15.5	115	3
Thallium bromide chloride	3.85	1.49	0.737	33.1	−9.2	136	1
Thallium bromide iodide	3.6	1.5	0.555	37	−11	180	1
Thorium	7.53	4.89	4.78	27.2	−10.7	20.9	2
W (tungsten)	50.1	19.8	15.14	2.57	−0.729	6.60	2
Zinc blende	10.0	6.5	3.4	20.5	−8.1	29.4	1
Zinc sulfide	10.79	7.22	4.12	20	−8.02	24.3	2

TABLE 2e-2. ELASTIC CONSTANTS AND COEFFICIENTS OF HEXAGONAL CRYSTALS
(C_{ij} in units of 10^{11} dynes/cm^2; S_{ij} in units of 10^{-13} cm^2/dyne)

Material	C_{11}	C_{33}	C_{44}	C_{12}	C_{13}	S_{11}	S_{33}	S_{44}	S_{12}	S_{13}	Ref.
Apatite	16.67	13.96	6.63	1.31	6.55	7.49	10.9	15.1	0.97	−4.0	23
$BaTiO_3$ (D = 0)	16.8	18.9	5.46	7.82	7.10	8.18	6.76	18.3	−2.98	−1.95	2
$BaTiO_3$ (E = 0)	16.6	16.2	4.29	7.66	7.75	8.55	8.93	23.3	−2.61	−2.85	2
$BaTiO_3$ 5% $CaTiO_3$ by wt. (E = 0)	17.41	16.88	4.74	7.93	8.00	8.05	8.42	21.1	−2.45	−2.65	2
Beryllium	30.8	35.7	11.0	−5.8	8.7	3.77	3.37	9.09	1.04	−1.17	1
Beryl I	27.81	24.8	6.61	10.01	6.77	4.27	4.47	15.1	−1.35	−0.80	1
Beryl II	29.71	26.5	7.54	10.26	7.39	3.97	4.21	13.3	−1.17	−0.78	1
Cadmium	11.0	4.69	1.56	4.04	3.83	12.9	36.9	64.0	−1.5	−9.3	2
CdS	8.1	8.0	1.43	4.9	4.8	22.2	21.9	70	−8.7	−8.0	21
Cobalt	30.7	35.81	7.53	16.5	10.3	4.72	3.19	13.24	−2.31	−0.69	2
Ice (−16°C)	1.33	1.42	0.306	0.63	0.46	101.3	82.8	326.5	−41.6	−19.3	22
Magnesium	5.97	6.17	1.64	2.62	2.17	22.0	19.7	61	−7.85	−5.0	2
SiO_2 (600°C) (β-quartz)	11.66	11.04	3.606	1.67	3.28	9.41	10.62	27.73	−0.60	−2.62	2
Yttrium	7.79	7.69	2.431	2.85	2.1	......	......	......	......	......	24
Zinc	16.1	6.10	3.83	3.42	5.01	8.38	28.38	26.1	0.53	−7.31	2

TABLE 2e-3. ELASTIC CONSTANTS AND COEFFICIENTS OF TETRAGONAL CRYSTALS
(C_{ij} in units of 10^{11} dynes/cm^2)

Material	C_{11}	C_{33}	C_{44}	C_{66}	C_{12}	C_{13}	Ref.
Ammonium dihydrogen phosphate	6.17	3.28	0.85	0.59	0.72	1.94	2
Ammonium dihydrogen phosphate	7.58	2.96	0.87	0.614	−2.43	1.30	2
Ammonium dihydrogen phosphate (D = 0)	6.76	3.38	0.867	0.687	0.59	2.0	2
Ammonium dihydrogen phosphate (E = 0)	6.76	3.38	0.867	0.608	0.59	2.0	2
Ammonium dihydrogen phosphate (deuterated)	6.2	3.0	0.91	0.61	−0.5	1.4	2
Barium titanate (D = 0)	28.3	17.8	8.05	11.3	18.7	14.2	2
Barium titanate (E = 0)	27.5	16.5	5.43	11.3	17.9	15.1	2
Indium	4.45	4.44	0.655	1.22	3.95	4.05	2
Nickel sulfate	3.21	2.93	1.16	1.78	2.31	0.21	1
Potassium dihydrogen arsenate	5.3	3.7	1.2	0.7	−0.6	−0.2	1
Potassium dihydrogen phosphate	7.14	5.62	1.27	0.628	−0.49	1.29	2
Potassium dihydrogen phosphate (0°C)	8.14	7.85	1.29	0.63	3.49	4.07	1
Sn (tin)	8.6	13.3	4.9	5.3	3.5	3.0	1
Sn	7.35	8.7	2.2	2.265	2.34	2.8	2
Sn	8.39	9.67	1.75	0.741	4.87	2.81	2
Zircon	7.35	4.60	1.38	1.60	0.90	−0.54	2

TABLE 2e-3A. ELASTIC CONSTANTS AND COEFFICIENTS OF TETRAGONAL CRYSTALS (*Continued*)
(S_{ij} in units of 10^{-13} cm^2/dyne)

Material	S_{11}	S_{33}	S_{44}	S_{66}	S_{12}	S_{13}	Ref.
Ammonium dihydrogen arsenate	16.9	44.5	152.9	124.0	−17.3	−11.1	3
Ammonium dihydrogen phosphate	20	45.7	117	169	1.7	−12.9	2
Ammonium dihydrogen phosphate	17.5	43.5	114	163	7.5	−11	2
Ammonium dihydrogen phosphate (D = 0)	18.1	43.5	115.3	145.5	1.9	−11.8	2
Ammonium dihydrogen phosphate (E = 0)	18.1	43.5	115.3	164.6	1.9	−11.8	2
Ammonium dihydrogen phosphate (deuterated)	19	44	110	164	2	−11	2
Barium titanate (D = 0)	7.25	10.8	12.4	8.84	−3.15	−3.26	2
Barium titanate (E = 0)	8.05	15.7	18.4	8.84	−2.35	−5.24	2
Indium	149.4	187	152.7	82	−50.6	−90.2	2
Nickel sulfate	65	34.3	86.5	56.2	−46.8	−1.3	1
Potassium dihydrogen arsenate	19	27	86.0	152	2	1	1
Potassium dihydrogen phosphate	14.8	19.5	78.7	159.2	1.7	−3.79	2
Potassium dihydrogen phosphate (0°C)	17.5	20	77.5	159	−4	−7	1
Sn (tin)	14.6	8.5	20.6	19.0	−5.3	−2.07	1
Sn	16.3	14.1	45.4	44.2	−3.6	−4.1	2
Sn	18.5	11.8	57.0	135	−9.9	−2.5	2
Zircon	13.9	22.1	72	62	−1.6	−1.4	2

TABLE 2e-4. ELASTIC CONSTANTS AND COEFFICIENTS OF TRIGONAL CRYSTALS
(C_{ij} in units of 10^{11} dynes/cm²)

Material	C_{11}	C_{33}	C_{44}	C_{12}	C_{13}	C_{14}	Ref.
Alumina (corundum)	46.5	56.3	23.3	12.4	11.7	10.1	2
Antimony	7.92	4.27	2.85	2.48	2.61	1.05	2
Bismuth	6.28	4.40	1.08	3.50	2.11	−0.42	2
Calespar (calcite)	13.74	8.01	3.42	4.40	4.50	−2.03	2
Dextrose sodium bromide	2.06	2.40	0.634	0.53	0.79	0.03	1
Dextrose sodium chloride	2.20	1.77	0.771	1.09	0.75	−0.03	1
Dextrose sodium iodide	2.58	2.06	0.771	1.52	0.49	−0.03	1
Haematite	24.2	22.8	8.5	5.5	1.6	−1.3	2
Mercury (−190 °C)	3.60	5.05	1.29	2.89	3.03	0.5	2
α-Quartz	8.674	10.72	5.79	0.699	1.191	−1.791	2
α-Quartz	8.75	10.77	5.73	0.762	1.51	1.72	2
Sapphire	49.6	50.2	20.6	10.9	4.8	3.8	25
Sodium nitrate	8.67	3.74	2.13	1.63	1.60	0.82	2
Tellurium	......	7.00	......	......	2.31	....	2
Tourmaline	27.2	16.5	6.5	4.0	3.5	−0.68	1
Tourmaline I	26.3	15.1	5.95	6.1	4.9	−0.9	1
Tourmaline II	30.4	17.6	6.5	8.8	3.5	−0.4	1

TABLE 2e-4A. ELASTIC CONSTANTS AND COEFFICIENTS OF TRIGONAL CRYSTALS (*Continued*)
(S_{ij} in units of 10^{-13} cm²/dyne)

Material	S_{11}	S_{33}	S_{44}	S_{12}	S_{13}	S_{14}	Ref.
Alumina (corundum)	2.90	1.94	5.78	−1.05	−0.38	−1.71	2
Aluminum phosphate	16.1	16.1	53.0	−0.1	−8.3	8.9	3
Antimony	17.7	33.8	41.0	−3.8	−8.5	−8.0	2
Bismuth	26.9	28.7	104.8	−14.0	−6.2	16.0	2
Calespar (calcite)	11.0	17.3	39.4	−3.4	−4.3	8.6	2
Dextrose sodium bromide	56.9	52.3	158	−8.6	−16.0	−3.4	1
Dextrose sodium chloride	63.8	70.2	130	−26.1	−16	3.6	1
Dextrose sodium iodide	60.2	51.6	130	−34.3	−6.2	3.8	1
Haematite	4.42	4.44	11.92	−1.02	−0.23	0.80	2
Lithium trisodium chromate	78.7	35.0	......	....	....	....	3
Lithium trisodium molybdate	29.5	27.1	......	....	....	....	3
Mercury (−190 °C)	154	45	151	−119	−21	−100	2
α-Quartz	12.77	9.6	20.04	−1.79	−1.22	4.50	2
α-Quartz	12.69	9.71	20.05	−1.69	−1.54	−4.31	2
Sapphire	2.18	2.02	5.04	−0.50	−0.16	−0.49	25
Sodium nitrate	13.4	30.8	51.5	−2.2	−4.8	−6.0	2
Tellurium	48.7	23.4	58.1	−6.9	−13.8	....	2
Tourmaline	3.85	6.36	15.4	−0.48	−0.71	0.45	1
Tourmaline I	4.22	7.34	17.1	−0.80	−1.11	0.76	1
Tourmaline II	3.64	5.89	15.4	−1.00	−0.53	0.29	1

TABLE 2e-5. ELASTIC CONSTANTS AND COEFFICIENTS OF ORTHORHOMBIC CRYSTALS
(C_{ij} in units of 10^{11} dynes/cm^2)

Material	C_{11}	C_{22}	C_{33}	C_{44}	C_{55}	C_{66}	C_{12}	C_{13}	C_{23}	Ref.
Aragonite	16.0	8.7	8.5	4.12	2.56	4.27	3.73	0.17	1.57	2
Baryte	8.62	9.17	10.84	1.20	2.87	2.74	5.23	3.41	3.56	1
Celestite	10.44	10.61	12.86	1.35	2.79	2.66	7.73	6.05	6.19	2
Iodic acid	3.03	5.45	4.36	1.84	2.19	1.74	1.19	1.17	0.55	1
Lithium ammonium tartrate	3.86	5.39	3.63	1.19	0.67	2.33	1.65	0.87	2.01	1
Magnesium sulfate	6.98	5.29	8.22	1.07	2.33	2.22	3.90	2.82	2.83	1
Potassium pentaborate	5.82	3.59	2.55	1.64	0.463	0.57	2.29	1.74	2.31	2
Rochelle salt ($D = 0$)	2.55	3.81	3.71	1.34	0.321	0.979	1.41	1.16	1.46	2
Rochelle salt ($E = 0$)	2.55	3.81	3.71	.....	0.286	0.960	1.41	1.16	1.46	2
Rochelle salt ($D = 0$)	4.25	5.15	6.29	1.25	0.304	0.996	2.96	3.57	3.42	2
Rochelle salt ($E = 0$)	4.25	5.15	6.29	0.58	0.278	0.974	2.96	3.57	3.42	2
Sodium ammonium tartrate	3.68	5.09	5.54	1.06	0.303	0.87	2.72	3.08	3.47	1
Sodium tartrate	4.61	5.47	6.65	1.24	0.31	0.98	2.86	3.20	3.52	1
Staurolite	34.3	18.5	14.7	4.6	7.0	9.2	6.7	6.1	12.8	26
Strontium formate	4.39	3.48	3.74	1.54	1.07	1.72	1.04	−1.49	−0.14	1
Sulfur	2.40	2.05	4.83	0.43	0.87	0.76	1.33	1.71	1.59	2
Topaz	28.2	34.9	29.5	10.8	13.3	13.1	12.6	8.5	8.8	2
α-Uranium	21.47	19.86	26.71	12.44	7.342	7.433	4.65	2.18	10.76	27
Zinc sulfate	4.00	3.22	5.45	0.50	1.70	1.81	1.32	1.80	1.19	1

TABLE 2e-5A. ELASTIC CONSTANTS AND COEFFICIENTS OF ORTHORHOMBIC CRYSTALS (*Continued*)
(S_{ij} in units of 10^{-13} cm^2/dyne)

Material	s_{11}	s_{22}	s_{33}	s_{44}	s_{55}	s_{66}	s_{12}	s_{13}	s_{23}	Ref.
Aragonite	6.95	13.2	12.2	24.3	39.0	23.4	−3.0	0.4	−2.4	2
Baryte	18.4	17.36	10.96	83.33	34.84	36.50	−9.45	−2.68	−2.73	1
Barium formate	.....	.....	.....	78.5	60.0	82.5	....	....	....	3
Celestite	22.0	21.9	11.4	74.1	35.8	37.6	−13.9	−3.7	−4.0	2
Iodic acid	39.8	20.1	25.6	54.5	45.6	57.6	−7.75	−9.7	−0.45	1
Lithium ammonium tartrate	30	25.6	35	84	150	43	−8.2	−2.7	−12.2	1
Magnesium sulfate	24.5	34.1	15.0	93.5	42.9	45.0	−16.6	−2.68	−6.05	1
Potassium pentaborate	23.2	73.6	98.3	61	215	175	−10.6	−6.1	−60	2
Rochelle salt (D = 0)	52.4	35.4	33.7	74.7	311	102	−15.4	−10.3	−9.1	2
Rochelle salt (E = 0)	52.4	35.4	33.7	......	350	104	−15.4	−10.3	−9.1	2
Rochelle salt (D = 0)	51.8	34.9	33.4	79.8	328	101	−15.3	−21.1	−10.3	2
Rochelle salt (E = 0)	51.8	34.9	33.4	174	360	103	−15.3	−21.1	−10.3	2
Sodium ammonium tartrate	57.0	38.5	40	94.5	330	115	−15.5	−22	−15.5	1
Sodium tartrate	37.1	31.6	26.4	80.6	323	102	−12.0	−11.5	−10.9	1
Strontium formate	28.4	31	31	65	93	58	−8	11	−2	1
Sulfur	71	83	30	232	115	132	−36	−13	−15	2
Topaz	4.43	3.53	3.84	9.23	7.53	7.63	−1.38	−0.86	−0.06	2
α-Uranium	4.91	6.73	4.79	8.04	13.62	13.45	−1.19	0.08	−2.61	27
Zinc sulfate	29.5	37.7	20.4	200	58.8	55.3	−10.8	−3.49	−6.10	1

TABLE 2e-6. ELASTIC CONSTANTS AND COEFFICIENTS OF MONOCLINIC CRYSTALS
(C_{ij} in units of 10^{11} dynes/cm^2; S_{ij} in units of 10^{-13} cm^2/dyne)

Material	C_{11}	C_{22}	C_{33}	C_{44}	C_{55}	C_{66}	C_{12}	C_{13}	C_{23}	C_{15}	C_{25}	C_{35}	C_{46}	Ref.
Dipotassium tartrate*	6.9	3.5	4.4	0.84	1.3	0.96	1.2	3.2	1.4	0.27	0.18	−0.13	−0.05	1
Ethylene diamine tartrate*	13.4	3.5	6.04	0.53	0.83	0.57	2.7	8.1	2.2	1.7	0.4	1.2	0.009	1
Lithium sulfate*	5.7	7.1	4.9	2.7	2.9	1.4	2.7	1.6	1.6	−0.22	1.6	0.14	0.17	1
Sodium thiosulfate*	3.31	3.02	4.57	0.57	1.11	0.60	1.83	1.84	1.68	0.25	1.04	−0.69	−0.27	1
Tartaric acid*	9.30	1.93	4.65	0.81	0.82	1.1	2.0	3.7	1.4	−1.2	−0.40	−0.036	0.14	1
	S_{11}	S_{22}	S_{33}	S_{44}	S_{55}	S_{66}	S_{12}	S_{13}	S_{23}	S_{15}	S_{25}	S_{35}	S_{46}	
Dipotassium tartrate*	22.4	33.7	38.6	119	81.5	104.1	−0.8	−16.4	−10.5	−6.4	−5.7	9.0	5.7	1
Ethylene diamine tartrate*	38.8	37	98	188	172	174	4.0	−52	−19	−7.0	1.0	−25	−3.0	1
Lithium sulfate*	23.9	21.3	23.1	36.9	41	74	−9.5	−5	−3.6	7.1	−12.0	0.5	−4.6	1
Sodium thiosulfate*	50.2	156	67.4	223	327	212	−32.3	−6.21	−71.9	15.2	−182	110	100	1
Tartaric acid*	21.6	77	38.5	130	180	96	−6.1	−15	−18	28	28	−29	−16	1
Dipotassium tartrate**	47.5	35.3	24.0	113.5	102	122.5	−17.4	−8	−6.2	−7.5	8.0	−14.0	−6.8	1
Ethylene diamine tartrate	33.4	36.5	100	192	117	191	−3	−30	−18	−17	15	−26.5	3.8	1
Lithium sulfate**	22.9	22.5	22.8	71.3	64.0	36.1	−5.4	−7.5	−4.6	−2.1	−8.3	6.3	1.4	1

* The single-starred values of the S_{ij} correspond to the single-starred values of the C_{ij}; that is, $(C^*)^{-1} = (S^*)$.
** The double-starred values are referred to a differently oriented set of axes.

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Abbreviations in Tables 2e-7 *through* 2e-16

Abbreviation	*Definition*
H.R.	Hot rolled
C.R.	Cold rolled
W.Q.	Water quenched
O.Q.	Oil quenched
A.Q.	Air quenched
A.C.	Air cooled
F.C.	Furnace cooled
h-t.	Heat-treated
wr.	Wrought
ann	Annealed
art. aged	Artificially aged
nat. aged	Naturally aged
spec	Specimen
G.S.	Grain size

TABLE 2e-7. ELASTIC AND STRENGTH CONSTANTS FOR SILVER, GOLD, PLATINUM, PALLADIUM ALLOYS

Material	Condition	E	σ	Tensile strength	Yield strength at 0.2% offset	Elongation	Reduction in area	Bhn	Ref.*
Ag	Strained 5%, heated 5 hr at 350°C	$7.1\text{–}7.8 \times 10^{11}$	....	....	....	....	....	....	1
Ag	Ann.	....	0.37	....	....	....	....	....	1
Ag + 80 Mo	....	....	....	55×10^8	....	....	....	190	1
Ag + 40 Mo	....	....	....	41×10^8	....	....	....	160	1
Ag + 20 Mo	....	....	....	24×10^8	....	....	....	40	1
Ag + 20 W	....	....	....	34×10^8	....	....	....	40	1
Ag + 40 W	....	....	....	41×10^8	....	....	....	150	1
Ag + 80 W	....	....	....	55×10^8	....	....	....	240	1
Ag + 40 Ni	Ann.	....	....	26×10^8	....	....	....	Vhn 70	1
Ag + 20 Ni	Ann.	....	....	21×10^8	....	....	....	Vhn 45	1
Ag + 1 graphite	....	....	....	....	....	....	....	$R_{15T}68$	1
Ag + 5 graphite	....	....	....	....	....	....	....	$R_{15T}55$	1
Ag + 10 graphite	....	....	....	....	....	....	....	$R_{15T}40$	1
Ag + 5 Cd	....	....	....	16×10^8	....	....	....	R_F30	1
Ag + 10 Cd	....	....	....	19×10^8	....	....	....	R_F44	1
Ag + 20 Cd	....	....	....	20×10^8	....	....	....	R_F55	1
33 Ag, 52 Hg, 12.5 Sn, 2 Cu, 0.5 Zn	....	1.0×10^{11}	....	$2.8\text{–}5.9 \times 10^8$	....	....	....	....	1
Au 99.99%	Cast	7.44×10^{11}	0.42	12.4×10^8	....	30	....	33	1
Au 99.99%	Wrought, ann.	8.00×10^{11}	0.42	13.1×10^8	Nil	45	....	25	1
58.3 Au, 4.9 Ag, 31.6 Cu, 5.2 Ni	Air cooled	....	....	56.9×10^8	33.1×10^8 at 0.1% offset	41.0	36.0	R_B87	1

TABLE 2e-7. ELASTIC AND STRENGTH CONSTANTS FOR SILVER, GOLD, PLATINUM, PALLADIUM ALLOYS (*Continued*)

Material	Condition	E	σ	Tensile strength	Yield strength at 0.2% offset	Elongation	Reduction in area	Bhn	Ref.*
41.6 Au, 4.6 Ag, 43.4 Cu, 5.0 Ni, 5.4 Zn	Air cooled	....	....	46.8×10^8	26.7×10^8 at 0.1% offset	41.5	36.0	R_B68	1
69 Au, 25 Ag, 6 Pt	Ann.	....	....	37.6×10^8	....	.....	....	Vhn 112	1
Pt 99.99%	Ann.	14.7×10^{11}	0.39	$12\text{–}13 \times 10^8$	....	25–40	....	Vhn 38–40	1
Pt + 5 Ir	Ann.	....	....	27×10^8	....	.....	....	90	1
Pt + 10 Ir	Ann.	....	....	38×10^8	....	.....	....	130	1
Pt + 25 Ir	Ann.	....	....	86×10^8	....	.....	....	240	1
Pt + 3.5 Rh	Ann.	....	....	17×10^8	....	.....	....	60	1
Pt + 5.0 Rh	Ann.	....	....	21×10^8	....	.....	....	70	1
Pt + 10.0 Rh	Ann.	....	....	31×10^8	....	35	....	90	1
Pt + 20.0 Rh	Ann.	....	....	48×10^8	....	40	....	120	1
Pt + 5 Ru	Ann.	....	....	41×10^8	....	.....	....	130	1
Pt + 10 Ru	Ann.	....	....	59×10^8	....	.....	....	190	1
Pt + 1 Ni	Ann.	....	....	21×10^8	....	.....	....	Vhn 60–65	1
Pt + 2 Ni	Ann.	....	....	28×10^8	....	.....	....	Vhn 80–90	1
Pt + 5 Ni	Ann.	....	....	45×10^8	....	.....	....	Vhn 130–140	1
84 Pt, 10 Pd, 6 Ru	Ann.	....	....	55×10^8	....	18–25	....	Vhn 150–170	1
96 Pt, 4 W	Ann.	....	....	$48\text{–}52 \times 10^8$	....	25	....	Vhn 140–150	1
Pd (pure)	Ann. and rolled	12.1×10^{11}	....	$\geq 15 \times 10^8$	....	24	....	Vhn 37–39	1
60 Pd, 40 Ag	Ann.	....	....	35×10^8	....	47	....	Vhn 100	1
60 Pd, 40 Cu	Ann.	....	....	52×10^8					
95 Pd, 4 Ru, 1 Rh	Ann.	....	....	$38\text{–}41 \times 10^8$	....	25	....	Vhn 100–110	1

* References are on p. 2-76.

TABLE 2c-8. ELASTIC AND STRENGTH CONSTANTS FOR ALUMINUM ALLOYS

Alloys	Condition	E	G	ν	Tensile strength	Yield strength	Elongation	Bhn	Shear strength	Ref.*
Cast alloys:										
Al, 12 Si	Die cast	7.10×10^{11}	2.65×10^{11}	0.33	25.5×10^{8}	12.4×10^{8}	1.8†			1
Al, 5 Si	Die cast	7.10×10^{11}	2.65×10^{11}	0.33	20.7×10^{8}	9.65×10^{8}	7.0†			1
Al, 5 Si	Sand cast	7.10×10^{11}	2.65×10^{11}	0.33	13.1×10^{8}	6.20×10^{8}	6.0‡	40¶	9.65×10^{8}	1
Al, 5 Si, 4 Cu	Die cast	7.10×10^{11}	2.65×10^{11}	0.33	27.6×10^{8}	15.2×10^{8}	3.5†			1
Al, 4 Cu, 3 Si	Sand cast	7.10×10^{11}	2.65×10^{11}	0.33	14.5×10^{8}	9.65×10^{8}	2.5‡	55¶	13.8×10^{8}	1
Al, 5 Si, 3 Cu	Sand cast	7.10×10^{11}	2.65×10^{11}	0.33	18.6×10^{8}	9.65×10^{8}	2.5‡	R_E65		1
Al, 5 Si, 3 Cu	Sand cast, h-t, aged	7.10×10^{11}	2.65×10^{11}	0.33	24.1×10^{8}	13.8×10^{8}	4.0‡	R_E80		1
Al, 5 Si, 3 Cu	Perm. mold cast, h-t, aged	7.10×10^{11}	2.65×10^{11}	0.33	28.9×10^{8}	15.2×10^{8}	5.0‡	R_E85		1
Al, 5.5 Si, 4.5 Cu	Perm. mold cast, h-t, aged	7.10×10^{11}	2.65×10^{11}	0.33	19.3×10^{8}	11.0×10^{8}	2.0‡	70¶	17.2×10^{8}	1
Al, 7 Cu, 2 Si, 1.7 Zn	Sand cast	7.10×10^{11}	2.65×10^{11}	0.33	16.5×10^{8}	10.3×10^{8}	1.5‡	70¶	13.8×10^{8}	1
Al, 7 Cu, 3.5 Si	Perm. mold cast	7.10×10^{11}	2.65×10^{11}	0.33	20.7×10^{8}	16.5×10^{8}	1.0‡	80¶	15.2×10^{8}	1
Al, 10 Cu, 0.2 Mg	Sand cast (ann.)	7.10×10^{11}	2.65×10^{11}	0.33	18.6×10^{8}	13.8×10^{8}	1.0‡	80¶	14.5×10^{8}	1
Al, 10 Cu, 0.2 Mg	H-t, artificially aged	7.10×10^{11}	2.65×10^{11}	0.33	27.6×10^{8}	20.7×10^{8}	0.5‡	115¶	20.0×10^{8}	1
Al, 12 Si, 2.5 Ni, 1.2 Mg, 0.8 Cu	Perm. mold cast, art. aged	7.10×10^{11}	2.65×10^{11}	0.33	24.8×10^{8}	19.3×10^{8}	0.5‡	105¶	16.5×10^{8}	1
Al, 12 Si, 1.5 Cu, 0.7 Mn, 0.7 Mg	Perm. mold cast (stress relieved)	7.10×10^{11}	2.65×10^{11}	0.33	24.8×10^{8}		0.5‡	100¶		1
Al, 4 Cu, 2 Ni, 1.5 Mg	Ann. (sand cast)	7.10×10^{11}	2.65×10^{11}	0.33	18.6×10^{8}	12.4×10^{8}	1.0‡	70¶	14.5×10^{8}	1
Al, 4.5 Cu	H-t, nat. aged	7.10×10^{11}	2.65×10^{11}	0.33	22.0×10^{8}	11.0×10^{8}	8.5‡	60¶	16.5×10^{8}	1
Al, 4.5 Cu, 2.5 Si	H-t, nat. aged	7.10×10^{11}	2.65×10^{11}	0.33	27.6×10^{8}	15.2×10^{8}	10.0‡	75¶	20.7×10^{8}	1
Al, 3.8 Mg	Perm. mold cast	7.10×10^{11}	2.65×10^{11}	0.33	18.6×10^{8}	11.0×10^{8}	7.0‡	60¶	15.2×10^{8}	1
Al, 8 Mg	Die cast	7.10×10^{11}	2.65×10^{11}	0.33	28.9×10^{8}	15.8×10^{8}	7.0†			1
Al, 10 Mg	Sand cast, h-t, nat. aged	7.10×10^{11}	2.65×10^{11}	0.33	31.7×10^{8}	17.2×10^{8}	14.0‡	75¶	22.7×10^{8}	1
Al, 6 Si, 3.5 Cu	H-t, art. aged	7.10×10^{11}	2.65×10^{11}	0.33	24.8×10^{8}	16.5×10^{8}	2.0‡	80¶		1
Al, 6 Si, 3.5 Cu	As cast	7.10×10^{11}	2.65×10^{11}	0.33	18.6×10^{8}	12.4×10^{8}	2.0‡	70¶	16.5×10^{8}	1
Al, 5 Si, 1.3 Cu, 0.5 Mg	H-t, art. aged (sand cast)	7.10×10^{11}	2.65×10^{11}	0.33	24.1×10^{8}	17.2×10^{8}	2.5‡	80¶	20.8×10^{8}	1
Al, 5 Si, 1.3 Cu, 0.5 Mg	H-t, art. aged (perm. mold cast)	7.10×10^{11}	2.65×10^{11}	0.33	29.6×10^{8}	18.6×10^{8}	4.0‡	90¶	20.8×10^{8}	1
Al, 7 Si, 0.3 Mg	H-t, art. aged (sand cast)	7.10×10^{11}	2.65×10^{11}	0.33	22.7×10^{8}	16.5×10^{8}	4.0‡	70¶	18.6×10^{8}	1
Al, 7 Si, 0.3 Mg	H-t, art. aged (perm. mold cast)	7.10×10^{11}	2.65×10^{11}	0.33	27.6×10^{8}	18.6×10^{8}	5.0‡	90¶		1
Al, 8 Si, 1.5 Cu, 0.3 Mg, 0.3 Mn	Sand cast (stress relieved)	7.10×10^{11}	2.65×10^{11}	0.33	20.7×10^{8}	14.5×10^{8}	1.5‡	R_E76		1
Al, 8 Si, 1.5 Cu, 0.3 Mg, 0.3 Mn	Perm. mold (stress relieved)	7.10×10^{11}	2.65×10^{11}	0.33	24.8×10^{8}		1.0‡	R_E88		1
Al, 9.5 Si, 0.5 Mg	Die cast	7.10×10^{11}	2.65×10^{11}	0.33	28.9×10^{8}	15.8×10^{8}	1.8†			1
Al, 8.5 Si, 3.5 Cu	Die cast	7.10×10^{11}	2.65×10^{11}	0.33	31.0×10^{8}	17.2×10^{8}	2.0†			1
Al, 6.5 Sn, 1 Cu, 1 Ni	(Perm. mold cast) art. aged	7.10×10^{11}	2.65×10^{11}	0.33	15.2×10^{8}	6.89×10^{8}	12.0‡	45¶	9.65×10^{8}	1
Al, 5.5 Zn, 0.6 Mg, 0.5 Cr, 0.2 Ti	Sand cast	7.10×10^{11}	2.65×10^{11}	0.33	24.1×10^{8}	17.2×10^{8}	5.0‡	80¶	19.2×10^{8}	1

Wrought alloys:										
Aluminum 99.996 Al	Ann.	6.89×10^{11}	2.65×10^{11}	0.33	4.74×10^{8}	1.22×10^{8}	48.8§	17¶		1
Aluminum 99.996 Al	Cold rolled 75%	6.89×10^{11}	2.65×10^{11}	0.33	11.2×10^{8}	10.6×10^{8}	5.5§	27¶		1
Aluminum 99.0+ Al	Ann.	6.89×10^{11}	2.65×10^{11}	0.33	8.96×10^{8}	3.45×10^{8}	35§	23¶	6.55×10^{8}	1
Aluminum 99.0+ Al	Hard H‖	6.89×10^{11}	2.65×10^{11}	0.33	16.6×10^{8}	14.5×10^{8}	5§	44¶	8.96×10^{8}	1
Al, 1.2 Mn	Ann.	6.89×10^{11}	2.65×10^{11}	0.33	11.0×10^{8}	4.14×10^{8}	30§	28¶	7.58×10^{8}	1
Al, 1.2 Mn	Hard H‖	6.89×10^{11}	2.65×10^{11}	0.33	20.0×10^{8}	17.2×10^{8}	4§	55¶	11.0×10^{8}	1
Al, 5.5 Cu, 0.5 Pb, 0.5 Bi	H-t, then cold-worked	7.10×10^{11}	2.65×10^{11}	0.33	36.5×10^{8}	32.4×10^{8}	15‡	95¶	20.7×10^{8}	1
Al, 5.5 Cu, 0.5 Pb, 0.5 Bi	H-t, then cold-worked, then art. aged	7.10×10^{11}	2.65×10^{11}	0.33	39.3×10^{8}	30.3×10^{8}	14‡	100¶	22.8×10^{8}	1
Al, 4 Cu, 0.6 Mn, 0.6 Mg, 0.5 Pb, 0.5 Bi	Quenched (h-t)	7.10×10^{11}	2.65×10^{11}	0.33	42.1×10^{8}	24.1×10^{8}	22§	100¶		1
Al, 4.4 Cu, 0.8 Si, 0.8 Mn, 0.4 Mg	Ann.	7.31×10^{11}	2.65×10^{11}	0.33	18.6×10^{8}	9.65×10^{8}	18‡	45¶	12.4×10^{8}	1
Al, 4.4 Cu, 0.8 Si, 0.8 Mn, 0.4 Mg	H-t, art. aged	7.31×10^{11}	2.65×10^{11}	0.33	48.3×10^{8}	41.4×10^{8}	13‡	135¶	29.0×10^{8}	1
Al, 4 Cu, 0.5 Mg, 0.5 Mn	Ann.	7.17×10^{11}	2.65×10^{11}	0.33	17.9×10^{8}	6.89×10^{8}	22§	45¶	12.4×10^{8}	1
Al, 4 Cu, 0.5 Mg, 0.5 Mn	H-t, nat. aged	7.17×10^{11}	2.65×10^{11}	0.33	42.7×10^{8}	27.6×10^{8}		105¶	26.2×10^{8}	1
Al, 4 Cu, 2 Ni, 0.5 Mg	Forged, h-t, aged	7.10×10^{11}	2.65×10^{11}	0.33	43.4×10^{8}	32.4×10^{8}	17‡	115¶		2
Al, 4 Cu, 2 Ni, 1.5 Mg	Sand cast	7.10×10^{11}	2.65×10^{11}	0.33	19.3×10^{8}	16.6×10^{8}	1‡	80¶	16.6×10^{8}	2
Al, 4.5 Cu, 1.5 Mg, 0.6 Mn	Ann.	7.31×10^{11}	2.65×10^{11}	0.33	18.6×10^{8}	7.58×10^{8}	19§	42¶	12.4×10^{8}	1
Al, 4.5 Cu, 1.5 Mg, 0.6 Mn	H-t, nat. aged	7.31×10^{11}	2.65×10^{11}	0.33	46.9×10^{8}	31.7×10^{8}	11§	120¶	28.3×10^{8}	1
Al, 4.5 Cu, 0.8 Mn, 0.8 Si	H-t, art. aged	7.17×10^{11}	2.65×10^{11}	0.33	39.3×10^{8}	24.1×10^{8}	18‡	110¶	24.1×10^{8}	1
Al, 12.5 Si, 1.0 Mg, 0.9 Cu, 0.9 Ni	H-t, art. aged	7.10×10^{11}	2.65×10^{11}	0.33	38.6×10^{8}	31.7×10^{8}	8‡	125¶	26.2×10^{8}	1
Al, 1.0 Si, 0.6 Mg, 0.25 Cr	H-t, art. aged	7.03×10^{11}	2.65×10^{11}	0.33	32.4×10^{8}	27.6×10^{8}	20‡	100¶	22.1×10^{8}	1
Al, 2.5 Mg, 0.25 Cr	Ann.	7.03×10^{11}	2.65×10^{11}	0.33	20.0×10^{8}	9.65×10^{8}	25§	45¶	12.4×10^{8}	1
Al, 2.5 Mg, 0.25 Cr	Strain hardened (H)	7.03×10^{11}	2.65×10^{11}	0.33	28.3×10^{8}	24.8×10^{8}	7§	85¶	16.6×10^{8}	1
Al, 1.3 Mg, 0.7 Si, 0.25 Cr	Ann.	6.89×10^{11}	2.65×10^{11}	0.33	11.0×10^{8}	4.83×10^{8}	35‡	26¶	7.58×10^{8}	1
Al, 1.3 Mg, 0.7 Si, 0.25 Cr	H-t, nat. aged	6.89×10^{11}	2.65×10^{11}	0.33	22.8×10^{8}	13.8×10^{8}	30‡	65¶	13.8×10^{8}	1
Al, 5.2 Mg, 0.1 Mn, 0.1 Cr	Ann.	7.10×10^{11}	2.65×10^{11}	0.33	29.0×10^{8}	13.8×10^{8}	35‡			1
Al, 5.2 Mg, 0.1 Mn, 0.1 Cr	Hard H‖	7.10×10^{11}	2.65×10^{11}	0.33	40.0×10^{8}	33.1×10^{8}	7‡			1
Al, 1.0 Mg, 0.6 Si, 0.25 Cu, 0.25 Cr	Ann.	6.89×10^{11}	2.65×10^{11}	0.33	12.4×10^{8}	5.52×10^{8}	22§	30¶	8.62×10^{8}	1
Al, 1.0 Mg, 0.6 Si, 0.25 Cu, 0.25 Cr	H-t, nat. aged	6.89×10^{11}	2.65×10^{11}	0.33	24.1×10^{8}	14.5×10^{8}	22§	65¶	16.5×10^{8}	1
Al, 5.5 Zn, 2.5 Mg, 1.5 Cu, 0.3 Cr, 0.2 Mn	Ann.	7.17×10^{11}	2.65×10^{11}	0.33	22.8×10^{8}	10.3×10^{8}	17§			1
Al, 5.5 Zn, 2.5 Mg, 1.5 Cu, 0.3 Cr, 0.2 Mn	H-t, art. aged	7.17×10^{11}	2.65×10^{11}	0.33	56.5×10^{8}	49.6×10^{8}	11§	150¶		1
Al, 6.4 Zn, 2.5 Mg, 1.2 Cu	Ann. (0.064 sheet)	7.17×10^{11}	2.69×10^{11}	0.33	20.7×10^{8}	10.3×10^{8}	13	R_E57–R_E62		1

* References are on p. 2-76.
† ¼-in. round specimen.
‡ ½-in. round specimen.
¶ 10-mm ball, 500-kg load.
§ 1/16-in. sheet specimen.
‖ H-strain hardened to a prescribed hardness.

TABLE 2c-9. ELASTIC AND STRENGTH CONSTANTS FOR COPPER ALLOYS

Alloy	Condition	E	G	σ	Tensile strength	Yield strength	Elongation	Reduction in area	Bhn	Shear strength	Ref.*
99.997 Cu, 0.0016 S	½-in. rod, cold drawn	12.77×10^{11}	4.68×10^{11}	0.364	35.1×10^8	34.0×10^8†	14	88	R_B37	....	2
99.996 Cu, 0.002 S, 0.002 Fe	Ann., ¾-in. rod	11.2×10^{11}	....	....	21.3×10^8	3.44×10^8†	60	92	......	....	2
99.950 Cu, 0.043 O_2, 0.002 Fe, 0.002 S	Ann., ¾-in. rod	10.9×10^{11}	....	....	21.7×10^8	3.79×10^8†	53	71	......	....	2
99.92 Cu, 0.04 O_2	H.R. (0.040-in. flat)	11.7×10^{11}	....	0.33 ± 0.01	23.4×10^8	6.89×10^8†	45	....	R_F45	15.8×10^8	1
99.94 Cu, 0.02 P	0.040 in. flat spec. (G.S. 0.050 mm)	11.7×10^{11}	....	....	22.0×10^8	6.89×10^8†	45	....	R_F40	15.2×10^8	1
95 Cu, 5 Zn	Rolled strip 0.040 in. (G.S. 0.050 mm)	11.7×10^{11}	....	....	23.4×10^8	6.89×10^8†	45	....	R_F46	....	1
95 Cu, 5 Zn	Rolled strip 0.040 in. (spring)	11.7×10^{11}	....	....	44.1×10^8	40.0×10^8†	4	....	R_B73	27.6×10^8	1
90 Cu, 10 Zn	Flat, 0.040 in. (spring)	11.7×10^{11}	....	....	49.6×10^8	42.7×10^8†	3	....	R_B78	28.9×10^8	1
90 Cu, 10 Zn	Flat, 0.040 in. as H.R.	11.7×10^{11}	....	....	26.9×10^8	9.65×10^8†	44	....	R_F60	21.4×10^8	1
85 Cu, 15 Zn	Flat, 0.040 in. (G.S. 0.050 mm)	11.7×10^{11}	....	....	27.6×10^8	8.27×10^8†	47	....	R_F59	21.4×10^8	1
85 Cu, 15 Zn	Flat, 0.040 in. (spring temper)	11.7×10^{11}	....	....	57.9×10^8	43.4×10^8†	3	....	R_B86	31.7×10^8	1
80 Cu, 20 Zn	Flat, 0.040 in. (G.S. 0.050 mm)	11.7×10^{11}	....	....	30.3×10^8	9.65×10^8†	50	....	R_F61	22.0×10^8	1
80 Cu, 20 Zn	Flat, 0.040 in. (spring temper)	11.0×10^{11}	....	....	62.7×10^8	44.8×10^8†	3	....	R_B91	33.1×10^8	1
70 Cu, 30 Zn	Flat, 0.040 in. (G.S. 0.070 mm)	11.0×10^{11}	....	....	31.7×10^8	9.65×10^8†	65	....	R_F58	22.0×10^8	1
70 Cu, 30 Zn	Flat, 0.040 in. (spring temper)	11.0×10^{11}	....	....	61.8×10^8	44.8×10^8†	3	....	R_B91	33.1×10^8	1
70 Cu, 30 Zn	Flat, 0.040 in. (extra spring temper)	11.0×10^{11}	....	....	68.2×10^8	44.8×10^8†	3	....	R_B93	....	1
65 Cu, 35 Zn	Flat, 0.040 in., ann.	10.3×10^{11}	....	....	33.8×10^8	11.7×10^8†	57	....	R_F68	23.4×10^8	1
65 Cu, 35 Zn	Flat, 0.040 in. (spring temper)	10.3×10^{11}	....	....	62.7×10^8	42.7×10^8†	3	....	R_B90	32.4×10^8	1
60 Cu, 40 Zn	Flat, 0.040 in., ann.	10.3×10^{11}	....	....	37.2×10^8	14.4×10^8†	45	....	R_F80	27.6×10^8	1
89 Cu, 9.25 Zn, 1.75 Pb	Rod, ann.	11.7×10^{11}	....	....	25.5×10^8	8.27×10^8†	45	70	R_F55	16.5×10^8	1
64.5 Cu, 35 Zn, 0.5 Pb	Flat specimen, ann.	10.3×10^{11}	....	....	33.8×10^8	11.7×10^8†	57	....	R_F68	23.4×10^8	1
67 Cu, 32.5 Zn, 0.5 Pb	Tubular specimen, ann.	10.3×10^{11}	....	....	32.4×10^8	10.3×10^8†	60	....	R_F64	....	1
64.5 Cu, 34.5 Zn, 1.0 Pb	Rolled, flat spec., ann.	10.3×10^{11}	....	....	33.8×10^8	11.7×10^8†	54	....	R_F68	23.4×10^8	1
62.5 Cu, 35.75 Zn, 1.75 Pb	Rolled, flat spec., ann.	10.3×10^{11}	....	....	33.8×10^8	11.7×10^8†	52	....	R_F68	23.4×10^8	1
62.5 Cu, 35 Zn, 2.5 Pb	Rolled, flat spec., ann.	9.65×10^{11}	....	....	33.8×10^8	11.7×10^8†	50	....	R_F68	21.4×10^8	1
61.5 Cu, 35.5 Zn, 3 Pb	Rod, ann.	9.65×10^{11}	....	....	33.8×10^8	12.4×10^8†	53	....	R_F68	20.7×10^8	1
60 Cu, 39.5 Zn, 0.5 Pb	H.R. 1-in. plate	10.3×10^{11}	....	....	37.2×10^8	13.8×10^8	45	....	R_F80	27.6×10^8	1
60.5 Cu, 38.4 Zn, 1.1 Pb	Light ann. 1.5-in. OD tubing	10.3×10^{11}	....	....	37.2×10^8	13.8×10^8	40	....	R_F80	....	1
60 Cu, 38 Zn, 2 Pb	Extruded 1-in. rod	10.3×10^{11}	....	....	35.8×10^8	13.8×10^8	45	....	R_F78	....	1
57 Cu, 40 Zn, 3 Pb	Extruded 1-in. section	9.65×10^{11}	....	....	41.3×10^8	13.8×10^8	30	....	R_B65	....	1
71 Cu, 28 Zn, 1 Sn	As H.R. (1-in. plate)	10.3×10^{11}	....	....	33.1×10^8	12.4×10^8†	65	....	R_F70	....	1
60 Cu, 39.25 Zn, 0.75 Sn	As H.R. (1-in. plate)	10.3×10^{11}	....	....	37.9×10^8	17.2×10^8†	50	....	R_B55	27.6×10^8	1

60 Cu, 37.5 Zn, 1.75 Pb, 0.75 Sn	1-in. rod, soft ann.	10.3×10^{11}	....	....	39.3×10^{8}	20.7×10^{8}†	40	....	R_B55	24.3×10^{8}	1
58.5 Cu, 39 Zn, 1.4 Fe, 1 Sn, 0.1 Mn	1-in. rod, soft ann.	10.3×10^{11}	....	....	44.8×10^{8}	20.7×10^{8}†	33	....	R_B65	28.9×10^{8}	1
95 Cu, 5 Sn	Ann., flat spec.	11.0×10^{11}	....	....	32.4×10^{8}	13.1×10^{8}	64	....	R_B26	....	1
92 Cu, 8 Sn	Ann., flat plate (0.040 in.)	11.0×10^{11}	....	....	37.9×10^{8}	....	70	....	R_F75	....	1
92 Cu, 8 Sn	Spring temper plate (0.040 in.)	11.0×10^{11}	....	....	77.2×10^{8}	....	3	....	R_B93	....	1
90 Cu, 10 Sn	Ann. flat plate (0.040 in.)	11.0×10^{11}	....	....	45.5×10^{8}	....	68	....	R_B55	....	1
90 Cu, 10 Sn	Spring, flat plate (0.040 in.)	11.0×10^{11}	....	....	84.1×10^{9}	....	4	....	R_B101	....	1
98.75 Cu, 1.25 Sn	Ann., flat plate (0.040 in.)	11.7×10^{11}	....	....	27.6×10^{8}	9.65×10^{8}	48	....	R_F60	....	1
98.75 Cu, 1.25 Sn	Spring, flat plate (0.040 in.)	11.7×10^{11}	....	....	51.7×10^{8}	....	4	....	R_B79	....	1
70 Cu, 30 Ni	H.R. 1-in. plate.	15.2×10^{11}	....	....	37.9×10^{8}	13.8×10^{8}	45	....	R_B35	....	1
65 Cu, 18 Ni, 17 Zn	Ann., flat plate (0.040 in.)	12.4×10^{11}	....	....	40.0×10^{8}	17.2×10^{8}	40	....	R_B40	....	1
55 Cu, 27 Zn, 18 Ni	Ann., flat plate (0.040 in.)	12.4×10^{11}	....	....	41.3×10^{8}	18.6×10^{8}	40	....	R_B55	....	1
55 Cu, 27 Zn, 18 Ni	Spring, flat plate (0.040 in.)	12.4×10^{11}	....	....	79.2×10^{8}	64.1×10^{8}	2.5	....	R_B99	....	1
Cu, 3 Si	Flat plate (0.040 in.) (G.S. 0.070 mm)	....	....	....	38.6×10^{8}	14.5×10^{8}†	63	....	R_B40	28.9×10^{8}	1
Cu, 3 Si	Flat plate (0.040 in.) spring	....	....	....	75.8×10^{8}	42.7×10^{8}†	4	....	R_B97	43.4×10^{8}	1
Cu, 1.5 Si	1-in. rod (G.S. 0.035 mm)	10.3×10^{11}	....	....	27.6×10^{8}	10.3×10^{8}†	50	....	R_F55	....	1
94.88 Cu, 5.02 Al, 0.04 Fe, 0.06 Zn	0.041-in. sheet, ann. at 500°C	....	....	....	41.5×10^{8}	17.6×10^{8}†	65.8	....	R_B48.5	....	1
94.88 Cu, 5.02 Al, 0.04 Fe, 0.06 Zn	0.041-in. sheet, C.R., 44% reduction	....	....	....	68.9×10^{8}	44.0×10^{8}†	8.0	....	R_B93.5	....	1
91.74 Cu, 8.10 Al, 0.04 Fe, 0.02 Ni, 0.10 Zn	0.020-in. sheet, ann. at 400°C	....	....	....	53.9×10^{9}	29.1×10^{8}†	41.8	....	....	....	1
91.74 Cu, 8.10 Al, 0.04 Fe, 0.02 Ni, 0.10 Zn	0.020-in. sheet, C.R., 37% reduction	....	....	....	62.7×10^{8}	45.3×10^{8}†	12.8	....	....	....	1
92.65 Cu, 7.35 Al	H.R.	....	....	....	43.4×10^{8}	....	73	....	134‡	....	1
92 Cu, 7 Al, 1 Ni	C.R., ann.	....	....	....	85.4×10^{8}	....	4.5	....	....	....	1
89.25 Cu, 9.25 Al, 0.6 Fe, 0.5 Ni	Ann., rod	....	....	....	55.1×10^{8}	27.6×10^{8}†	22	....	....	....	1
87.45 Cu, 5.62 Al, 6.93 Ni	H.R.	....	....	....	75.7×10^{8}	71.2×10^{8}	20	....	241‡	....	1
85.75 Cu, 10.75 Al, 3.50 Fe	Sand cast	....	....	....	62.0×10^{8}	25.5×10^{8}†	14	....	175§	....	1
81.3 Cu, 10.7 Al, 4.0 Fe, 4.0 Ni	Forged, ann. at 845°C	11.2×10^{11}	....	....	65.1×10^{8}	41.4×10^{8}	28.0	....	R_B90	....	1
Cu, 2 Be, 0.25 Co (or 0.35 Ni)	Solution treated, quenched	11.7×10^{11}	....	....	49.6×10^{8}	17.2×10^{8}¶	50	....	R_B60	....	1
88 Cu, 6 Sn, 1.5 Pb, 4.5 Zn	Sand cast 0.505-in. section	8.96×10^{11}	....	....	26.2×10^{8}	11.0×10^{8}†	35	35	66‡	....	1
87 Cu, 8 Sn, 1 Pb, 4 Zn	Sand cast 0.505-in. section	9.65×10^{11}	....	....	24.8×10^{8}	12.4×10^{8}†	30	....	68‡	....	1
85 Cu, 5 Sn, 9 Pb, 1 Zn	Sand cast 0.505-in. section	....	....	....	20.7×10^{8}	10.3×10^{8}†	15	16	60‡	....	1
83 Cu, 7 Sn, 7 Pb, 3 Zn	Sand cast 0.505-in. section	9.99×10^{11}	....	....	23.4×10^{8}	11.7×10^{8}†	20	18	60‡	....	1
80 Cu, 10 Sn, 10 Pb	Sand cast 0.505-in. section	7.58×10^{11}	....	....	22.0×10^{8}	11.7×10^{8}†	12	10.0	65‡	....	1
78 Cu, 7 Sn, 15 Pb	Sand cast	7.23×10^{11}	....	....	20.7×10^{8}	11.0×10^{8}†	15	15	55‡	....	1
70 Cu, 5 Sn, 25 Pb	Sand cast	6.89×10^{11}	....	....	14.5×10^{8}	....	10	8	48‡	....	1
85 Cu, 5 Sn, 5 Pb, 5 Zn	Sand cast	9.30×10^{11}	....	....	23.4×10^{8}	11.7×10^{8}†	25	25	60‡	....	1
83 Cu, 4 Sn, 6 Pb, 7 Zn	Sand cast	....	....	....	22.0×10^{8}	10.3×10^{8}†	24	20	55‡	....	1
81 Cu, 3 Sn, 7 Pb, 9 Zn	Sand cast	8.96×10^{11}	....	....	22.0×10^{8}	10.3×10^{8}†	22	20	55‡	....	1

See page 2-76 for footnotes.

TABLE 2e-9. ELASTIC AND STRENGTH CONSTANTS FOR COPPER ALLOYS (*Continued*)

Alloy	Condition	E	G	σ	Tensile strength	Yield strength	Elongation	Reduction in area	Bhn	Shear strength	Ref.*
76 Cu, 3 Sn, 6 Pb, 15 Zn	Sand cast	8.27×10^{11}	....	....	22.0×10^{8}	10.3×10^{8}†	30	30	55‡	....	1
71 Cu, 1 Sn, 3 Pb, 25 Zn	Sand cast 0.505-in. section	8.96×10^{11}	....	....	24.1×10^{8}	8.27×10^{8}†	35	30	48‡	....	1
66 Cu, 1 Sn, 3 Pb, 30 Zn	Sand cast 0.505-in. section	8.96×10^{11}	....	....	23.4×10^{8}	8.96×10^{8}†	35	30	50‡	....	1
60 Cu, 1 Sn, 1 Pb, 38 Zn	Sand cast	9.65×10^{11}	....	....	27.6×10^{8}	9.65×10^{8}†	25	25	65‡	....	1
63 Cu, 26 Zn, 3 Fe, 5.5 Al, 3.5 Mn	Sand cast	10.7×10^{11}	....	....	79.2×10^{8}	48.2×10^{8}†	15	15	210§	....	1
58 Cu, 39.25 Zn, 1.25 Fe, 1.25 Al, 0.25 Mn	Sand cast	10.3×10^{11}	....	....	48.2×10^{8}	19.3×10^{8}†	30	30	125‡	....	1
59 Cu, 0.75 Sn, 0.75 Pb, 37 Zn, 1.25 Fe, 0.75 Al, 0.5 Mn	Sand cast	10.3×10^{11}	....	....	44.8×10^{8}	20.7×10^{8}†	18	20	85‡	....	1
66 Cu, 5 Sn, 1.5 Pb, 2 Zn, 25 Ni	Sand cast	....	....	....	34.4×10^{8}	16.5×10^{8}†	15	15	130‡	....	1
64 Cu, 4 Sn, 4 Pb, 8 Zn, 20 Ni	Sand cast	....	....	....	27.6×10^{8}	17.2×10^{8}†	15	14	105‡	....	1
57 Cu, 2 Sn, 9 Pb, 20 Zn, 12 Ni	Sand cast	....	....	....	23.4×10^{8}	10.3×10^{8}†	20	20	60‡	....	1
60 Cu, 3 Sn, 5 Pb, 16 Zn, 16 Ni	Sand cast	....	....	....	26.2×10^{8}	11.7×10^{8}†	25	25	75‡	....	1
89 Cu, 1 Fe, 10 Al	Sand cast, cooled in sand	....	....	....	46.2×10^{8}	22.0×10^{8}†	15	15	140§	....	1
87.5 Cu, 3.5 Fe, 9 Al	Sand cast	11.7×10^{11}	....	....	51.7×10^{8}	18.6×10^{8}†	35	32	120§	....	1
86 Cu, 4 Fe, 10 Al	Sand cast, cooled in sand	12.4×10^{11}	....	....	51.7×10^{8}	24.1×10^{8}†	18	15	155§	....	1
79 Cu, 5 Fe, 11 Al, 5 Ni	Sand cast	11.7×10^{11}	....	....	65.5×10^{8}	31.0×10^{8}†	7	7	195§	....	1

* References are on p. 2–76.
† At 0.5% extension.
‡ 10-mm ball, 500-kg load.
¶ At 0.01% offset.
§ 10-mm ball, 3,000-kg load.

TABLE 2e-10, ELASTIC AND STRENGTH CONSTANTS FOR VARIOUS SOLIDS

Material	Condition	E	G	Tensile strength	Yield strength at 0.2% offset	Elongation	Bhn	Ref.*
Iridium	Ann.	52×10^{11}	...	...	...	...	Vhn 170	1
Osmium	Ann.	56×10^{11}	...	...	...	...	Vhn 400	1
Rhodium	Ann.	...	...	50×10^{8}	...	...	...	1
Ruthenium	As cast	41×10^{11}	...	...	...	...	Vhn 390	1
Antimony	...	7.78×10^{11}	...	1.1×10^{8}	...	...	30–58	1
Beryllium	Vacuum cast	29×10^{11}	...	$12\text{–}15 \times 10^{8}$	...	...	...	1
Cadmium	Chill cast 1-in. section	5.5×10^{11}†	...	7.1×10^{8}	...	50	21–23	1
Calcium	Cast slab	$2\text{–}3 \times 10^{11}$	...	5.5×10^{8}	3.8×10^{8}	53–60	17	1
Chromium	As cast	...	...	...	...	...	110–170	1
Cobalt	Cast	21×10^{11}	...	23.7×10^{8}	...	...	125	1
Columbium	Sheet, ann. 0.01-in. section	...	...	34×10^{8}	...	30	...	1
Columbium	Sheet, worked 0.01-in. section	...	...	69×10^{8}	...	1	...	1
Lithium	...	...	...	...	...	...	Softer than pure lead	1
Manganese	Quenched	...	...	50×10^{8}	24×10^{8}	40	R_C35	1
Molybdenum	Pressed + sintered (sheet)	34×10^{11}	...	69×10^{8}	...	...	156	1
Silicon	Chill cast 3.55 × 0.97 × 0.97 in.	11.26×10^{11}	...	...	...	...	...	1
Sodium	...	...	...	...	...	...	0.07‡	1
Tantalum	Ann. 0.010-in. sheet	...	...	34×10^{8}	...	40	R_F60	1
Tantalum	Worked 0.010-in. sheet	...	...	76×10^{8}	...	1	R_F95	1
Titanium	Ann.	11.6×10^{11}	...	54×10^{8}	43×10^{8}	25.2	R_G76	1
Titanium	Hard, 60% reduction	...	...	76.82×10^{8}	...	1.5	R_G72	1
Tungsten	...	34×10^{11}	13.5×10^{11}	...	...	...	...	1
Zirconium	Hard drawn	9.99×10^{11}	...	84×10^{8}	48×10^{8}	18¶	$R_B87.4$	1

* References are on p. 2-76.
† Sand cast.
‡ 3.2-kg load, 10-mm ball.
¶ Per cent in 4 in.

Table 2c-11. Elastic and Strength Constants for Iron and Steel Alloys

% C	Alloy	Condition	E	G	σ	Tensile strength	Yield strength	Elongation	Reduction in area	Bhn	Shear strength	Ref.*
	Iron:											
	2.50 C, 0.79 Si, 0.09 S, 0.04 P	Cast	13.8×10^{11}	...	...	32.8×10^{8}	...	...	...	266	30.7×10^{8}	2
	3.52 C, 2.55 Si, 1.01 Mn, 0.215 P, 0.086 S	⅞-in. cast, ann. bar	12.1×10^{11}	5.10×10^{11}	...	23.5×10^{8}	...	...	...	163	30.2×10^{8}	2
	3.52 C, 2.55 Si, 1.01 Mn, 0.215 P, 0.086 S	2-in. bar	8.27×10^{11}	43.4×10^{11}	...	15.5×10^{8}	...	...	...	164	25.1×10^{8}	2
	1.15–2.30 C, 0.85–1.20 Si, 0.40 Mn, 0.020 P, 0.012 S	Malleable, cast, ann.	17.2×10^{11}	8.61×10^{11}	0.17	39.3×10^{8}	25.8×10^{8}†	22	...	111–145	33.1×10^{8}	2
	2.25–2.70 C, 0.80–1.10 Si	...	17.2×10^{11}	8.61×10^{11}	0.17	34.4×10^{8}	22.4×10^{8}†	14	...	...	33.1×10^{8}	2
	Steel:											
0.03	0.12 Mn, 0.005 Si, 0.45 Cu, 0.07 Mo	H.R. at 540°C	...	...	...	34.3×10^{8}	24.0×10^{8}†	35.8	65	...	...	12
0.02	0.5 Cu	As normalized	...	...	...	34×10^{8}	27×10^{8}‡	46	78	...	...	1
0.02	1.0 Cu	As normalized	...	...	...	39×10^{8}	31×10^{8}‡	41	73	...	...	1
0.02	1.5 Cu	As normalized	...	...	...	48×10^{8}	43×10^{8}‡	36	70	...	...	1
0.02	2.0 Cu	As normalized	...	...	...	55×10^{8}	50×10^{8}‡	31	67	...	...	1
0.02	2.5 Cu	As normalized	...	...	...	56×10^{8}	52×10^{8}‡	27	66	...	...	1
0.02	3.0 Cu	As normalized	...	...	...	56×10^{8}	52×10^{8}‡	26	65	...	...	1
0.05	0.39 Si, 0.25 Mn, 0.014 P, 0.049 S	As rolled	...	...	...	40.0×10^{8}	27.9×10^{8}‡	29.5¶	72	117	...	1
0.07	1.17 Si, 0.32 Mn, 0.013 P, 0.034 S	As rolled	...	...	...	46.5×10^{8}	32.7×10^{8}‡	29.5¶	71.5	130	...	1
0.05	1.73 Si, 0.35 Mn, 0.014 P, 0.030 S	As rolled	...	...	...	50.0×10^{8}	37.6×10^{8}‡	29.5¶	64	140	...	1
0.06	2.39 Si, 0.16 Mn, 0.010 P, 0.016 S	As rolled	...	...	...	52.7×10^{8}	36.9×10^{8}‡	24.5¶	53.5	181	...	1
0.054	0.42 Mn, 0.025 Si, 0.031 Al, 0.265 Ti	H.R., 5% strained, aged	...	...	...	48.9×10^{8}	46.9×10^{8}‡	11.9§	67.0	...	...	13
0.025	0.30 Mn, 0.010 P, 0.023 S, 0.09 Ni, 0.09 Cu, 0.26 V	Annealed	...	...	...	29.2×10^{8}	15.8×10^{8}‡	28.1	...	...	...	1
0.08	1.01 Cr, 0.41 Cu, 0.80 Si, 27 Mn, 0.145 P, 0.020 S	H.R. ¾-in. bar	20.7×10^{11}	8.20×10^{11}	...	54.0×10^{8}	41.3×10^{8}‖	40	72	156	...	2
0.07	18.95 Cr, 7.69 Ni	C.R. ⅜-in. bar	17.2×10^{11}	...	...	98.5×10^{8}	...	21††	...	302	...	2
0.03	13.47 Cr, 0.27 V, 0.04 P, 0.01 S	H.R. 3⅜-in. bar	18.2×10^{11}	8.54×10^{11}	...	56.8×10^{8}	...	16§	26	175	47.2×10^{8}	2
0.08	1.07 Cu, 0.54 Ni, 0.43 Mn, 0.16 Si, 0.104 P, 0.022 S	H.R. ¾-in. bar	20.5×10^{11}	7.92×10^{11}	...	48.8×10^{8}	38.7×10^{8}**	38	69	145	...	2
0.08	1.46 Si, 0.102 Mn	W.Q. from 1830°F	20.9×10^{11}	...	...	63.7×10^{8}	47.1×10^{8}**	16	...	...	...	2
0.10	0.45 Mn, 3.71 Ni, 0.10 S	A.C. from 1550°F	...	...	...	60.4×10^{8}	34.4×10^{8}†	37	72	138	...	4
0.10	0.5 Cr, 0.3 Mo, 2.5 Ni	O.Q. from 820°C (carburized)	...	...	...	93.1×10^{8}	78.4×10^{8}†	13‡‡	...	...	...	5
0.10	0.6 Cr, 0.3 Mo, 3.3 Ni	O.Q. from 820°C (carburized)	...	...	...	122×10^{8}	108×10^{8}†	10‡‡	...	...	...	5
0.10	0.07 Si, 0.69 Mn, 0.092 P, 0.027 S, 0.16 Al, 1.09 Cu, 0.15 Mo, 0.63 Ni	H.R. 4 hr at 540°C	...	...	...	52.8×10^{8}	39.2×10^{8}†	45.8	...	...	...	6
0.11	0.6 Mn, 1.4 Cr, 0.17 Mo, 1.0 Ni	W.Q. from 900°C (carburized)	...	...	...	85.8×10^{8}	60.8×10^{8}†	12.8¶¶	...	...	...	5
0.12	0.84 Mn, 0.12 S, 0.099 P, 0.01 Si	1⅛-in. diam C.R. bar	20.9×10^{11}	...	...	57.4×10^{8}	52.4×10^{8}	18	52	Vhn 205	...	2
0.15	0.75 Mn, 0.30 Si, 1.75 Ni, 0.25 Mo	Cast	...	...	...	68.9×10^{8}	44.8×10^{8}†	20.0	35.0	200	...	7
0.15	0.75 Mn, 0.30 Si, 3.50 Ni	Cast	...	...	...	68.9×10^{8}	44.8×10^{8}†	20.0	35.0	200	...	7
0.16	0.4 Mn, 1.2 Cr, 0.25 Mo, 4.1 Ni	O.Q. from 780 to 180°	...	...	...	135×10^{8}	120×10^{8}†	15.8	50.0	...	...	8
0.15	13.50 Cr, 0.11 Si	O.Q. from 1740°F, T at 1110°F	21.5×10^{11}	...	...	90.9×10^{8}	75.8×10^{8}	21	63	85	...	2
0.17	0.5 Mn, 0.25 Mo, 1.8 Ni	P.(O.Q.)(carburized)	...	...	...	83.8×10^{8}	66.8×10^{8}†	21.2	52.1	...	...	9
0.18	0.55 Mn, 0.25 Si	...	...	...	...	45×10^{8}	25×10^{8}†	32.0	53.0	130	...	7
0.18	2.50 Cr, 0.55 Mn, 0.40 Si, 0.40 Mo, 0.20 V	Cast	...	...	...	96.5×10^{8}	82.7×10^{8}†	15.0	50.0	...	...	7
0.18	0.92 Mn, 0.115 P, 0.12 S, 0.02 Si	C.R.	20.5×10^{11}	...	...	67.6×10^{8}	45.5×10^{8}	15	46	...	...	2
0.20	16.17 Cr, 1.06 Mn, 0.30 Si	O.Q. from 1740°F, T at 840°F	22.5×10^{11}	...	...	130×10^{8}	61.2×10^{8}	10	...	357	...	2

0.19	1.35 Mn, 0.10 S	W.Q. from 1550°F	...	...	...	89.6 × 10⁸†	60.8 × 10⁸	16	44	251	...	4
0.20	0.46 Cr, 1.19 Mn, 0.67 Si, 0.033 P, 0.019 S	Rolled	20.9 × 10¹¹	82.0 × 10¹¹	0.276	59.0 × 10⁸	37.4 × 10⁸	30	....	156	56.0 × 10⁸	2
0.25	0.45 Mn, 0.40 S, 0.03 Si, 0.012 P	Rolled, ¼-in. plate	20.4 × 10¹¹	...	0.306	43.5 × 10⁸	22.3 × 10⁸	40	70	122	...	2
0.25	to 0.35	...	20.3 × 10¹¹	78.5 × 10¹¹	0.297	...	...	...	....	...	...	2
0.15	to 0.25; 0.3–0.6 Mn, 0.045 P, 0.05 S	H.R.	20.53 × 10¹¹	78.06 × 10¹¹	0.313	...	...	...	....	...	...	10
0.15	to 0.25; 0.3–0.6 Mn, 0.045 P, 0.05 S	C.R.	20.12 × 10¹¹	78.20 × 10¹¹	0.286	...	...	...	....	...	...	10
0.27	0.72 Mn, 0.21 Si, 0.024 S, 0.014 P	Wr., ann. at 1450°F, F.C.	18.9 × 10¹¹	81.3 × 10¹¹	0.316	46.4 × 10⁸	25.8 × 10⁸	46	64	153	52.3 × 10⁸	2
0.27	0.72 Mn, 0.21 Si, 0.024 S, 0.014 P	Wr. W.Q. from 1600°F, T at 1100°F	20.4 × 10¹¹	82.7 × 10¹¹	0.310	62.8 × 10⁸	37.9 × 10⁸	42	70	191	...	2
0.19	0.85 Mn, 0.05 (max) S, 0.045 (max) P	H.R. (trans. prop.)	...	...	...	42.6 × 10⁸	22.5 × 10⁸	36.0	53.7	...	...	1
0.19	0.85 Mn, 0.05 (max) S, 0.045 (max) P	H.R. (long. prop.)	...	...	...	44.1 × 10⁸	25.0 × 10⁸	43.5§§	66.5	...	...	1
0.10	0.75 Mn, 0.20 S, 0.10 P	H.R. (trans. prop.)	...	...	...	43.1 × 10⁸	24.7 × 10⁸	22.6§§	24.5	...	...	1
0.10	0.75 Mn, 0.20 S, 0.10 P	H.R. (long. prop.)	...	...	...	46.1 × 10⁸	27.5 × 10⁸	37.5§§	60.5	...	...	1
0.30	0.70 Mn, 3.5 Ni	Ann.	...	...	...	54.7 × 10⁸	39.3 × 10⁸	31.5	57.2	...	...	1
0.34	0.88 Mn, 0.35 Si, 0.035 S, 0.019 P	Rolled ¾-in. plate	20.5 × 10¹¹	...	0.291	59.5 × 10⁸	24.1 × 10⁸‖‖	33	58	168	...	2
0.38	0.65 Mn, 0.22 Si	Wr., ann. at 1450°F, F.C.	19.8 × 10¹¹	8.06 × 10¹¹	0.287	52.2 × 10⁸	28.6 × 10⁸‖‖	44	56	146	55.0 × 10⁸	2
0.91	0.38 Mn, 0.16 Si, 0.036 P	O.Q. from 1575°F, T at 940°F	20.8 × 10¹¹	7.44 × 10¹¹	...	155 × 10⁸	99.2 × 10⁸‖‖	7	....	444	...	2
1.04	0.36 Mn, 0.16 Si, 0.018 S, 0.015 P	½ hr at 1550°F, O.Q. from 120°F, T ½ hr at 800°F	20.5 × 10¹¹	7.44 × 10¹¹	...	163 × 10⁸	99.2 × 10⁸‖‖	5	....	...	...	2
0.37	0.50 Cr, 1.14 Mn, 0.84 Si, 0.033 S, 0.021 P	H.R. ¾-in. bar	21 × 10¹¹	...	...	86.1 × 10⁸	55.6 × 10⁸‖	23	58	255	...	2
0.60	0.56 Cr, 0.62 Mn, 0.26 Si	O.Q. from 1470°F, T at 750°F	21.1 × 10¹¹	8.27 × 10¹¹	...	164 × 10⁸	...	2.5§	2.0	469	...	2
0.45	1.14 Cr, 0.69 Mn, 0.12 Si	N at 1525°F	21 × 10¹¹	...	...	83.4 × 10⁸	61.7 × 10⁸	12§	50	250	...	2
0.33	0.78 Cr, 0.24 Mo, 0.54 Mn, 0.21 Si, 0.025 P, 0.029 S	W., F.C. from 1450°F	19.7 × 10¹¹	8.27 × 10¹¹	0.288	52.8 × 10⁸	29.3 × 10⁸	48	66	170	60.2 × 10⁸	2
0.33	0.78 Cr, 0.24 Mo, 0.54 Mn, 0.21 Si, 0.025 P, 0.029 S	Wr., O.Q. from 1600°F, T at 1100°F	19.8 × 10¹¹	8.13 × 10¹¹	0.272	83.8 × 10⁸	62.4 × 10⁸	28	60	229	78.5 × 10⁸	2
0.34	0.46 Mn, 21.30 Cr, 10.95 Ni, 3.16 W, 1.39 Si	A.C. from 1740°F	20.1 × 10¹¹	...	...	88.2 × 10⁸	30.9 × 10⁸***	25	35	269	...	2
0.37	1.18 Cr, 0.16 V, 0.71 Mn, 0.33 Si, 0.037 S, 0.024 P	Wr., F.C. from 1450°F	20.3 × 10¹¹	8.13 × 10¹¹	0.289	61.1 × 10⁸	33.0 × 10⁸	42	62	179	61.7 × 10⁸	2
0.31	1.66 Mn, 0.25 Si, 0.024 S, 0.015 P	Wr. F.C. from 1450°F	19.2 × 10¹¹	8.27 × 10¹¹	0.295	58.5 × 10⁸	29.8 × 10⁸	42	54	169	58.1 × 10⁸	2
0.43	3.47 Ni, 0.64 Mn, 0.20 Si, 0.023 S, 0.015 P	Wr. F.C. from 1450°F	21 × 10¹¹	8.34 × 10¹¹	0.308	65.0 × 10⁸	36.5 × 10⁸	33	45	187	60 × 10⁸	2
0.40	1.65 Ni, 0.99 Cr, 0.51 Mn, 0.20 Si, 0.028 S, 0.019 P	Wr., F.C. from 1450°F	19.8 × 10¹¹	7.78 × 10¹¹	0.299	61.9 × 10⁸	30.2 × 10⁸	40	54	170	62.4 × 10⁸	2
0.32	1.92 Ni, 0.86 Cr, 0.30 Mo, 0.60 Mn, 0.16 Si, 0.019 S, 0.014 P	Wr., F.C. from 1450°F	19.8 × 10¹¹	7.02 × 10¹¹	0.288	66.2 × 10⁸	34.2 × 10⁸	37	58	202	66.0 × 10⁸	2
0.32	2.42 Ni, 0.49 Cr, 0.38 Mo, 0.88 Mn, 0.23 Si, 0.13 Cu, 0.04 S, 0.03 P	Cast ann. at 1575°F, 6-in. bar, T at 1200°F	20.2 × 10¹¹	7.92 × 10¹¹	...	81.3 × 10⁸	67.5 × 10⁸	10†††	16	260	72.3 × 10⁸	2
1.27	12.69 Mn, 0.12 Si	W.Q. from 1830°F	...	...	...	102 × 10⁸	53.2 × 10⁸	44	49	...	...	1
0.78	0.10 Mn	Ann. at 1472°F	...	...	...	63.2 × 10⁸	65.4 × 10⁸	12	35	...	...	1

* References are on p. 2–76.
† At yield point.
‡ At 0.2% offset.
¶ % in 70 mm.
§ % in 8 in.
‖ At 0.005% permanent set.
** At 0.05% permanent set.
†† % in 1.5 in.
‡‡ % in 3.94 in.
¶¶ % in 1.97 in.
§§ % in 0.75 in.
‖‖ At 0.001% permanent set.
*** At 0.1% offset.
††† % in $4/\sqrt{\text{area}}$.

TABLE 2c-12. ELASTIC AND STRENGTH CONSTANTS FOR LEAD AND LEAD ALLOYS

Alloy	Condition	E	σ	Tensile strength	Yield strength at 0.5% offset	Elongation, % in 2 in.	Reduction in area	Bhn	Shear strength	Ref.*
99.90 Pb	Rolled, aged	......	......	1.77×10^8	0.95×10^8	22	......	R_B75	......	1
99.73 Pb	Sand cast	1.38×10^{11}	......	$1.1\text{–}1.3 \times 10^8$	0.55×10^8	30	100	3.2–4.5	1.2×10^8	1
99.73 Pb	Chill cast	......	0.40–0.45	1.4×10^8	......	47	100	4.2	......	1
0.023–0.033 Ca, 0.02–0.1 Cu, 0.002–0.02 Ag	Extruded	......	......	2.1×10^8	......	40	......	......	......	1
1 Sb	Extruded and aged	1.38×10^{11}	......	2.1×10^8	......	50	......	7	......	1
4 Sb	Rolled, 95% reduction	......	......	2.77×10^8	......	48.3	......	8.1	......	1
6 Sb	Chill cast	......	......	4.71×10^8	......	24	......	13.0	......	1
6 Sb	Extruded	......	......	2.27×10^8	......	65	......	10.7	......	1
6 Sb	Cold rolled, 95% reduction	......	......	2.82×10^8	......	47	......		......	1
8 Sb	Rolled, 95% reduction	......	......	3.20×10^8	......	31.3	......	9.5†	......	1
9 Sb	Chill cast	......	......	5.2×10^8	......	17	......	15.4	......	1
4.5–5.5 Sn	......	......	......	2.3×10^8	1.0×10^8	50	80	8	......	1
20 Sn	......	......	......	4.0×10^8	2.51×10^8	16	50	11.3	......	1
50 Sn	......	......	......	4.2×10^8	3.3×10^8	60	70	14.5	4.04×10^8	1
4.50–5.50 Sn, 9.25–10.75 Sb	Chill cast	2.89×10^{11}	......	6.9×10^8	......	5	......	19	......	1
4.50 + 5.50 Sn, 14–16 Sb	Chill cast	2.89×10^{11}	......	6.9×10^8	......	5	......	20	......	1
9.3–10.7 Sn, 14–16 Sb	Cast	2.89×10^{11}	......	7.2×10^8	......	4	......	22	......	1
0.75–1.25 Sn, 0.8–1.4 As, 14.5–17.5 Sb	Chill cast	2.89×10^{11}	......	7.1×10^8	......	2	......	20	......	1
0.6–1.0 Sn, 1.5–3.0 As, 12.0–13.5 Sb	Chill cast	2.89×10^{11}	......	6.8×10^8	......	1.5	......	22	......	1

* References are on p. 2–76.

† $\frac{1}{16}$-in. ball, 9.85-kg load for 30 sec.

TABLE 2e-13. ELASTIC AND STRENGTH CONSTANTS FOR MAGNESIUM ALLOYS

Alloy	Condition	E	G	σ	Tensile strength	Yield strength at 0.2% offset	Elongation, % in 2 in.	Bhn	Shear strength	Ref.*
99.9+ Mg	....	4.48×10^{11}	1.67×10^{11}	0.35						
8.3–9.7 Al, 0.10 Mn, 1.7–2.3 Zn, ≤0.3 Si, ≤0.05 Cu, ≤0.01 Ni, 0.3 other	Sand and permanent cast molds, as fabricated	4.48×10^{11}	1.67×10^{11}	0.35	16.5×10^8	9.65×10^8	2	65	13.1×10^8	14
8.3–9.7 Al, 0.10 Mn, 1.7–2.3 Zn, ≤0.3 Si, ≤0.05 Cu, ≤0.01 Ni, 0.3 other	Sand and permanent cast molds, cast and stabilized	4.48×10^{11}	1.67×10^{11}	0.35	16.5×10^8	9.65×10^8	2	..	13.1×10^8	14
8.3–9.7 Al, 0.10 Mn, 1.7–2.3 Zn, ≤0.3 Si, ≤0.05 Cu, ≤0.01 Ni, 0.3 other	Sand and permanent cast, solution h-t	4.48×10^{11}	1.67×10^{11}	0.35	27.6×10^8	9.65×10^8	10	63	13.8×10^8	14
5.3–6.7 Al, ≥0.15 Mn, 2.5–3.5 Zn, ≤0.3 Si, ≤0.05 Cu, ≤0.01 Ni, 0.3 other	Sand and permanent cast molds, as fabricated	4.48×10^{11}	1.67×10^{11}	0.35	20.0×10^8	9.65×10^8	6	50	12.4×10^8	14
5.3–6.7 Al, ≥0.15 Mn, 2.5–3.5 Zn, ≤0.3 Si, ≤0.05 Cu, ≤0.01 Ni, 0.3 other	Sand and permanent cast molds, cast and stabilized	4.48×10^{11}	1.67×10^{11}	0.35	20.0×10^8	9.65×10^8	5	..	13.1×10^8	14
5.3–6.7 Al, ≥0.15 Mn, 2.5–3.5 Zn, ≤0.3 Si, ≤0.05 Cu, ≤0.01 Ni, 0.3 other	Sand and permanent cast molds, solution h-t	4.48×10^{11}	1.67×10^{11}	0.35	27.6×10^8	9.65×10^8	12	55	13.1×10^8	14
8.3–9.7 Al, ≥0.13 Mn, 0.4–1.0 Zn, ≤0.5 Si, ≤0.10 Cu, ≤0.01 Ni, 0.3 other	Sand and permanent cast molds, as fabricated	4.48×10^{11}	1.67×10^{11}	0.35	16.5×10^8	9.65×10^8	2	52	....	14
8.3–9.7 Al, ≥0.13 Mn, 0.4–1.0 Zn, ≤0.5 Si, ≤0.10 Cu, ≤0.01 Ni, 0.3 other	Sand and permanent cast molds, solution h-t	4.48×10^{11}	1.67×10^{11}	0.35	27.6×10^8	9.65×10^8	11	53	....	14
8.3–9.7 Al, ≥0.13 Mn, 0.4–1.0 Zn, ≤0.5 Si, ≤0.10 Cu, ≤0.01 Ni, 0.3 other	Sand and permanent cast, solution h-t, aged	4.48×10^{11}	1.67×10^{11}	0.35	27.6×10^8	13.1×10^8	4	66	....	14
8.3–9.7 Al, ≥0.13 Mn, 0.4–1.0 Zn, ≤0.5 Si, 0.10 Cu, ≤0.01 Ni, 0.3 other	Die cast, as fabricated	4.48×10^{11}	1.67×10^{11}	0.35	22.7×10^8	15.2×10^8	3	60	13.8×10^8	14
8.3–9.7 Al, ≥0.10 Mn, 0.4–1.0 Zn, ≤0.5 Si, ≤0.3 Cu, ≤0.01 Ni, 0.3 other	Die cast, as fabricated	4.48×10^{11}	1.67×10^{11}	0.35	22.7×10^8	15.2×10^8	3	60	13.8×10^8	14
2.5–3.5 Al, ≥0.20 Mn, 0.6–1.4 Zn, 0.08–0.30 Ca, ≤0.3 Si, ≤0.05 Cu, ≤0.005 Fe, ≤0.005 Ni, 0.3 other	Sheet, ann.	4.48×10^{11}	1.67×10^{11}	0.35	25.5×10^8	15.2×10^8	21	56	14.5×10^8	14
2.5–3.5 Al, ≥0.20 Mn, 0.6–1.4 Zn, 0.08–0.30 Ca, ≤0.3 Si, ≤0.05 Cu, ≤0.005 Fe, ≤0.005 Ni, 0.3 other	Sheet, hard rolled	4.48×10^{11}	1.67×10^{11}	0.35	28.9×10^8	22.0×10^8	16	73	15.8×10^8	14

TABLE 2e-13. ELASTIC AND STRENGTH CONSTANTS FOR MAGNESIUM ALLOYS (*Continued*)

Alloy	Condition	E	G	σ	Tensile strength	Yield strength at 0.2% offset	Elongation, % in 2 in.	Bhn	Shear strength	Ref.*
2.5–3.5 Al, $\geq$0.20 Mn, 0.6–1.4 Zn, 0.08–0.30 Ca, $\leq$0.3 Si, $\leq$0.05 Cu, $\leq$0.005 Fe, $\leq$0.005 Ni, 0.3 other	Sheet, as fabricated	4.48×10^{11}	1.67×10^{11}	0.35	25.5×10^8	15.2×10^8	21	..	14.5×10^8	14
$\geq$1.20 Mn, 0.08–0.14 Ca, $\leq$0.3 Si, $\leq$0.05 Cu, $\leq$0.01 Ni, 0.3 other	Sheet, ann.	4.48×10^{11}	1.67×10^{11}	0.35	22.7×10^8	12.4×10^8	16	48	12.4×10^8	14
$\geq$1.20 Mn, 0.08–0.14 Ca, $\leq$0.3 Si, $\leq$0.05 Cu, $\leq$0.01 Ni, 0.3 other	Sheet, hard rolled	4.48×10^{11}	1.67×10^{11}	0.35	25.5×10^8	19.3×10^8	7	56	11.7×10^8	14
$\leq$1.20 Mn, 0.08–0.14 Ca, $\leq$0.3 Si, $\leq$0.05 Cu, $\leq$0.01 Ni, $\leq$0.3 other	Sheet, as fabricated	4.48×10^{11}	1.67×10^{11}	0.35	22.7×10^8	....	..	..	....	14
5.8–7.2 Al, 0.15 Mn, 0.4–1.5 Zn, $\leq$0.3 Si, $\leq$0.05 Cu, $\leq$0.005 Ni, $\leq$0.005 Fe, +0.3 other	Extruded bars, rods, or shapes, as fabricated	4.48×10^{11}	1.67×10^{11}	0.35	30.3×10^8	20.7×10^8	14	60	13.1×10^8	14
7.8–9.2 Al, $\geq$0.15 Mn, 0.2–0.8 Zn, $\leq$0.3 Si, $\leq$0.05 Cu, $\leq$0.005 Ni, $\leq$0.005 Fe, 0.3 other	Extruded bars, rods, or shapes, as fabricated	4.48×10^{11}	1.67×10^{11}	0.35	33.1×10^8	22.0×10^8	12	60	15.2×10^8	14
7.8–9.2 Al, $\geq$0.15 Mn, 0.2–0.8 Zn, $\leq$0.3 Si, $\leq$0.05 Cu, $\leq$0.005 Ni, $\leq$0.005 Fe, 0.3 other	Extruded bars, rods, or shapes, aged	4.48×10^{11}	1.67×10^{11}	0.35	35.8×10^8	24.8×10^8	5	82	16.5×10^8	14
$\geq$0.06 Mn, 4.3–6.2 Zn, $\geq$0.45 Zr, 0.3 other	Extruded bars, rods, or shapes, as fabricated	4.48×10^{11}	1.67×10^{11}	0.35	33.8×10^8	26.2×10^8	12	75	16.5×10^8	14
$\geq$0.06 Mn, 4.3–6.2 Zn, $\geq$0.45 Zr, 0.3 other	Extruded bars, rods, or shapes, aged	4.48×10^{11}	1.67×10^{11}	0.35	35.1×10^8	28.9×10^8	10	82	17.2×10^8	14

* References are on p. 2–76.

TABLE 2e-14. ELASTIC AND STRENGTH CONSTANTS FOR NICKEL AND NICKEL ALLOYS

Alloy	Condition	E	σ	Tensile strength	Yield strength at 0.2% offset	Elongation	Reduction in area	Bhn	Shear strength	Ref.*
63–70 Ni, $\leq$2.5 Fe, $\leq$2.0 Mn, remainder Cu	Wr., ann.	....	....	51.7×10^8	24.1×10^8	40	.....	125	$34–44 \times 10^8$	15
63–70 Ni, $\leq$2.5 Fe, $\leq$2.0 Mn, remainder Cu	Wr., H.R.	17.9×10^{11}	....	62.0×10^8	34.4×10^8	35	.....	150	$34–44 \times 10^8$	15
63–70 Ni, $\leq$2.5 Fe, $\leq$2.0 Mn, remainder Cu	Wr., cold drawn	....	....	68.9×10^8	55.1×10^8	25	.....	190	$34–44 \times 10^8$	15
63–70 Ni, $\leq$2.5 Fe, $\leq$2.0 Mn, remainder Cu	Wr., C.R. (hard temper)	....	....	75.8×10^8	68.9×10^8	5	.....	240	$34–44 \times 10^8$	15
63–70 Ni, 2.0–4.0 Al, 0.25–1.0 Ti, remainder Cu	H.R.	18×10^{11}	0.32	68.9×10^8	31.0×10^8	40	.....	160	....	15
63–70 Ni, 2.0–4.0 Al, 0.25–1.0 Ti, remainder Cu	H.R., age hardened	18×10^{11}	....	103×10^8	75.8×10^8	25	.....	280	....	15
63–70 Ni, 2.0–4.0 Al, 0.25–1.0 Ti, remainder Cu	Cold drawn	18×10^{11}	....	79.2×10^8	58.6×10^8	25	.....	210	....	15
63–70 Ni, 2.0–4.0 Al, 0.25–1.0 Ti, remainder Cu	Cold drawn; age hardened	18×10^{11}	....	107×10^8	79.2×10^8	20	.....	290	....	15
$\geq$99.0 Ni, $\leq$0.15 C, $\leq$0.35 Mn, $\leq$0.40 Fe	Wr., ann.	21×10^{11}	0.31	48.2×10^8	13.8×10^8	40	.....	100	36×10^8	15
$\geq$99.0 Ni, $\leq$0.15 C, $\leq$0.35 Mn, $\leq$0.40 Fe	Wr., H.R.	....	....	51.7×10^8	17.2×10^8	40	.....	110	....	15
$\geq$99.0 Ni, $\leq$0.15 C, $\leq$0.35 Mn, $\leq$0.40 Fe	Wr., cold drawn	....	....	65.4×10^8	48.2×10^8	25	.....	170	....	15
$\geq$99.0 Ni, $\leq$0.15 C, $\leq$0.35 Mn, $\leq$0.40 Fe	Wr., cold rolled (hard temper)	....	....	72.3×10^8	65.4×10^8	5	.....	210	....	15
$\geq$99.0 Ni, $\leq$0.02 C	Ann.	21×10^{11}	0.31	41.3×10^8	10.3×10^8	50	.....	90	....	15
$\geq$93.0 Ni, 4.00–4.75 Al, 0.25–1.0 Ti, $\leq$0.30 C	H.R.	21×10^{11}	0.31	72.3×10^8	34.4×10^8	35	.....	180	....	15
$\geq$93.0 Ni, 4.00–4.75 Al, 0.25–1.0 Ti, $\leq$0.30 C	H.R., age hardened	....	....	117×10^8	89.6×10^8	15	.....	320	....	15
$\geq$93.0 Ni, 4.00–4.75 Al, 0.25–1.0 Ti, $\leq$0.30 C	Cold drawn	....	....	82.7×10^8	62.0×10^8	25	.....	220	....	15
$\geq$93.0 Ni, 4.00–4.75 Al, 0.25–1.0 Ti, $\leq$0.30 C	Cold drawn; age hardened	....	....	121×10^8	93.0×10^8	15	.....	340	....	15

* References are on page 2-76.

TABLE 2c-14. ELASTIC AND STRENGTH CONSTANTS FOR NICKEL AND NICKEL ALLOYS (*Continued*)

Alloy	Condition	E	σ	Tensile strength	Yield strength at 0.2% offset	Elongation	Reduction in area	Bhn	Shear strength	Ref.*
≥72.0 Ni, 14.0–17.0 Cr, 6.0–10.0 Fe, ≤0.15 C	Wr., ann.	....	....	58.6×10^8	24.1×10^8	45	.....	150	....	15
≥72.0 Ni, 14.0–17.0 Cr, 6.0–10.0 Fe, ≤0.15 C	Wr., H.R.	....	....	68.9×10^8	41.3×10^8	35	.....	180	....	15
≥72.0 Ni, 14.0–17.0 Cr, 6.0–10.0 Fe, ≤0.15 C	Wr., cold drawn	....	....	79.2×10^8	62.0×10^8	20	.....	200	....	15
≥72.0 Ni, 14.0–17.0 Cr, 6.0–10.0 Fe, ≤0.15 C	Wr., C.R. (hard temper)	....	....	93.0×10^8	75.8×10^8	5	.....	260	....	15
≤70.0 Ni, 14.0–16.0 Cr, 5.0–9.0 Fe, 2.25–2.75 Ti, 0.4–1.0 Al, 0.7–1.2 Cb (+Ta)	Ann.	21×10^{11}	....	79.2×10^8	34.4×10^8	50	.....	200	....	15
≥70.0 Ni, 14.0–16.0 Cr, 5.0–9.0 Fe, 2.25–2.75 Ti, 0.4–1.0 Al, 0.7–1.2 Cb (+Ta)	H.R., age hardened	21×10^{11}	....	124×10^8	82.7×10^8	25	.....	360	....	15
63 Ni, 30 Cu, 4 Si, 2 Fe +	Sand cast	14.5×10^{11}	....	$76\text{–}100 \times 10^8$	$55\text{–}79 \times 10^8$	1–4	.....	275–350	....	1
57 Ni, 20 Mo, 20 Fe +	Ann.	18.6×10^{11}	....	$76\text{–}83 \times 10^8$	$32.4\text{–}36 \times 10^8$	40–48	40–54	200–215	....	1
62 Ni, 30 Mo, 5 Fe +	Rolled, ann.	21.19×10^{11}	....	$90\text{–}96 \times 10^8$	$41\text{–}45 \times 10^8$	40–45	40–45	210–235	....	1
58 Ni, 17 Mo, 15 Cr, 5 W, 5 Fe +	Ann. plate	19.6×10^{11}	....	$79\text{–}88 \times 10^8$	$38\text{–}45 \times 10^8$	25–50	.....	160–210	....	1
85 Ni, 10 Si, 3 Cu +	Sand cast	19.88×10^{11}	....	$25\text{–}27.9 \times 10^8$	....	......	.....	....	....	1
80 Ni, 14 Cr, 6 Fe +	Ann.	21×10^{11}	....	....	19.3×10^8	......	.....	....	41.9×10^8	1
58 Ni, 22 Cr, 6 Cu, 6 Mo, 6 Fe	Sand cast	18.38×10^{11}	....	$41\text{–}50 \times 10^8$	....	4–9.5	8–11	160–210	....	1
80 Ni, 20 Cr +	Ann.	21×10^{11}	....	65.4×10^8	....	25–35	55	Rn85–90	....	1

* References are on p. 2–76.

TABLE 2e-15. ELASTIC AND STRENGTH CONSTANTS FOR TIN AND TIN ALLOYS

Alloy	Condition	E	σ	Tensile strength	Yield strength at 0.2% offset	Elongation	Bhn	Shear strength	Ref.*
Pure tin	Cast	$4.1–4.5 \times 10^{11}$	....	2.14×10^8	....	55	5.3	2.00×10^8	1
Pure tin	Chill cast	....	....	1.45×10^8	....	69	......	....	1
Pure tin	0.1-in. sheet, ann.	....	....	1.65×10^8	....	96	....	....	1
99.8 Sn†	Cast	4.13×10^{11}	....	1.45×10^8	....	54†	....	....	1
99.8 Sn†	Ann., 0.040-in. sheet	4.13×10^{11}	0.33	1.52×10^8	....	45	Vhn 7.2	0.896×10^8	1
95 Sn, 5 Sb	Cast	....	....	4.06×10^8	....	38†	....	4.13×10^8	1
95 Sn, 5 Ag	0.040-in. sheet, aged at room temp.	....	....	3.17×10^8	2.48×10^8	49	....	....	1
70 Sn, 30 Pb	Cast	....	....	4.68×10^8	....	...	12	....	1
63 Sn, 37 Pb	Cast	....	....	5.17×10^8	....	32†	14	4.27×10^8	1
91 Sn, 4.5 Sb, 4.5 Cu	Chill cast	5.03×10^{11}	....	6.41×10^8	4.34×10^8‡	...	17	....	1
83.4 Sn, 8.3 Sb, 8.3 Cu	Chill cast	....	....	....	5.51×10^8‡	...	27	....	1

* References are on p. 2–76.
† % in 4 in.
‡ At 0.3% offset.

TABLE 2e-16. ELASTIC AND STRENGTH CONSTANTS FOR ZINC AND ZINC ALLOYS

Alloy	Condition	Tensile strength	Elongation, % in 2 in.	Bhn	Shear strength	Ref.*
3.5–4.3 Al, 0.03–0.08 Mg	Die cast, ¼-in. section	28×10^3	10	82	21×10^3	1
3.5–4.3 Al, 0.75–1.25 Cu, 0.03–0.08 Mg	Die cast, ¼-in. section	33×10^3	7	91	26×10^3	1
3.5–4.5 Al, 2.5–3.5 Cu, 0.02–0.10 Mg	Die cast, ¼-in. section	35.9×10^3	8	100	32×10^3	1
4.5–5.0 Al, 0.2–0.3 Cu	Chill cast, ½-in. section	19×10^3	.....	...	....	1
5.25–5.75 Al	Chill cast, ½-in. section	17×10^3	1	...	....	1
≤0.10 Pb	H.R. strip	$13.4–16 \times 10^3$	50–65	38	....	1
0.05–0.10 Pb, 0.05–0.08 Cd	H.R. strip	$14–17 \times 10^3$	30–52	43	....	1
0.25–0.50 Pb, 0.25–0.45 Cd	H.R. strip	$16–20 \times 10^3$	32-50	47	....	1
0.85–1.25 Cu	H.R. strip	$16–22 \times 10^3$	15–20	52	....	1
0.85–1.25 Cu, 0.006–0.016 Mg	H.R. strip	$19–25 \times 10^3$	10–20	61	....	1

* References are below.

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TABLE 2e-17. DIFFUSION COEFFICIENTS FOR METALS

Metal	Test temp.	$D\left(\frac{cm^2}{sec}\right)$	Ref.
Ag into Ag	Room	0.895	1
Ag into Ag	460°C	8.0×10^{-14}	11
Ag into Ag	600°C	5.9×10^{-12}	11
Ag into Ag	666°C	2.45×10^{-11}	2
Ag into Ag	794°C	3.64×10^{-10}	2
Ag into Ag	936°C	4.61×10^{-9}	2
Al into Cu	Room	1.75×10^{-2}	1
Au into Au	Room	0.160	3
Au into Cu	Room	0.1 ± 0.06	4
Be into Cu	Room	2.32×10^{-4}	1
Bi into Pb	Room	0.018	3
Cd into Cu	Room	1.97×10^{-9}	3
Cd into Ag	Room	7.3×10^{-5}	3
Cd into Pb	Room	1.8×10^{-3}	3
Cl^- into NaCl single crystals	650°C	7.25×10^{-11}	5
Cl^- into NaCl single crystals	681°C	2.84×10^{-10}	5
Cl^- into NaCl single crystals	703°C	6.76×10^{-10}	5
Cl^- into NaCl single crystals	735°C	1.67×10^{-9}	5
Cl^- into NaCl single crystals	762°C	2.52×10^{-9}	5
Cu into Cu	Room	0.1-47	1
Cu into Cu	700°C	4.06×10^{-12}	7
Cu into Cu	900°C	3.58×10^{-10}	7
Cu into Cu	1000°C	1.95×10^{-9}	7
Cu into CuO	800°C	0.19×10^{-8}	6
Cu into CuO	900°C	0.77×10^{-8}	6
Cu into CuO	1000°C	3.2×10^{-8}	6
Cu into Ag	Room	5.95×10^{-5}	1
In into In	49.95°C	$7\text{-}8.5 \times 10^{-13}$	9
In into In	87.25°C	$1.4\text{-}1.5 \times 10^{-11}$	9
In into In	155.50°C	1.14×10^{-9}	9
In into In	155.81°C	1.70×10^{-7}	9
In into In	156.60°C	6.52×10^{-6}	9
In into In	157.30°C	1.23×10^{-5}	9
In into Ag	Room	4.85×10^{-5}	1
Liq. Hg into liq. Hg	2.5°C	1.52×10^{-5}	8
Liq. Hg into liq. Hg	16.4°C	1.68×10^{-5}	8
Lig. Hg into liq. Hg	23.0°C	1.79×10^{-5}	8
Liq. Hg into liq. Hg	31.9°C	1.88×10^{-5}	8
Liq. Hg into liq. Hg	41.5°C	1.98×10^{-5}	8
Liq. Hg into liq. Hg	66.1°C	2.24×10^{-5}	8
Liq. Hg into liq. Hg	91.2°C	2.57×10^{-5}	8
Mn into Cu	Room	0.72×10^{-5}	1
Ni into Cu	Room	6.5×10^{-5}	1
Ni into Pb	Room	0.66	1
Pd into Cu	Room	0.16×10^{-5}	1

TABLE 2e-17. DIFFUSION COEFFICIENTS FOR METALS (*Continued*)

Metal	Test temp.	$D\left(\frac{cm^2}{sec}\right)$	Ref.
Pt into Cu	Room	1.02×10^{-4}	1
Pb into Pb	Room	6.6	1
Sb into Ag	Room	5.31×10^{-5}	1
Si into ferrite	1435 ± 5°C	1.1×10^{-7}	10
Si into Cu	Room	3.7×10^{-2}	1
Sn into Ag	Room	7.82×10^{-5}	1
Sn into Cu	Room	1.13	1
Sn into Pb	Room	3.96	1
Ti into In	49.27°C	1.4×10^{-12}	9
Ti into In	74.19°C	9.2×10^{-12}	9
Ti into In	101.55°C	$4.6–4.8 \times 10^{-11}$	9
Ti into In	139.16°C	$2.8–3.2 \times 10^{-10}$	9
Ti into In	155.60°C	2.17×10^{-9}	9
Ti into In	155.91°C	1.87×10^{-7}	9
Ti into In	157.80°C	2.27×10^{-5}	9
Ti into Pb	Room	0.025	1

N. B. The values quoted from ref. 1 are for D_0 in the equation $D = D_0e^{-H/RT}$. Cf. ref. 1 for values of H.

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10. Bradshaw, F. J., G. Hoyle, and K. Speight: *Nature* **171**, 488 (1953).
11. Kuczynski, G. C.: *J. Appl. Phys.* **21**, 632 (1950).

7. *Rockwell Hardness Number.*[1] "A hardness value indicated on a direct-reading dial when a designated load is imposed on a metallic material in the Rockwell hardness testing machine using a steel ball or a diamond penetrator. The value must be qualified by reference to the load and penetrator used. Several scales are in common use: Rockwell A hardness is determined with a minor load of 10 kg and a major load of 60 kg using the diamond cone (brale); Rockwell B hardness is determined with a minor load of 10 kg and a major load of 100 kg using a $\frac{1}{16}$-in. steel ball; Rockwell C hardness is determined with a minor load of 10 kg and a major load of 150 kg using the diamond cone"; Rockwell D hardness is determined with a minor load of 10 kg and a major load of 100 kg using a diamond cone indenter; Rockwell E hardness is determined with a minor load of 10 kg and a major load of 100 kg using a $\frac{1}{8}$-in. steel ball indenter; Rockwell F hardness is determined with a minor load of 10 kg and a major load of 60 kg using a $\frac{1}{16}$-in. steel ball; Rockwell G hardness is determined with a minor load of 10 kg and a major load of 150 kg, using a $\frac{1}{16}$-in. steel ball indenter.

A second set of Rockwell hardness numbers are the Rockwell superficial hardness numbers. One of these is the Rockwell 15T hardness, which is determined with a minor load of 3 kg and a major load of 15 kg, using a $\frac{1}{16}$-in. steel ball.

Note: The methods of determining the hardness values can be found in Standard Methods of Test for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials, ASTM E18-42.

8. *Brinell Hardness Number.*[2] "A hard spherical indenter of diameter D mm is pressed into the metal surface under a load W kg and the mean chordal diameter of the resultant indentation measured (d mm). The Brinell hardness number (Bhn) is defined as

$$\text{Bhn} = \frac{W}{\text{curved area of indentation}} = \frac{2W}{\pi D(D - \sqrt{D^2 - d^2})}$$

and is expressed in kg/mm².'"

9. *Vickers Hardness Number.*[2] "A pyramidal diamond indenter is pressed into the surface of a metal under a load of W kg and the mean diagonal of the resultant indentation measured (d mm). The Vickers hardness number (Vhn), or Vickers diamond hardness (Vdh), is defined as

$$\text{Vdh (or Vhn)} = \frac{W}{\text{pyramidal area of indentation}}$$

The indenter has an angle of 136° between opposite faces and 146° between opposite edges. From simple geometry, this means that the pyramidal area of the indentation is greater than the projected area of the indentation by the ratio 1:0.9272. Hence

$$\text{Vdh} = \frac{0.9272W}{\text{projected area of indentation}} = 1.8544W/d^2$$

The value is expressed in kg/mm²."

10. *Diffusion Coefficient.* If the concentration (mass of solid per unit volume of solution) at one surface of a layer of liquid is d_1, and at the other surface d_2, the thickness of the layer is h, the area under consideration is A, and the mass of a given substance which diffuses through the cross section A in time t is m, then the diffusion coefficient is defined as

$$D = \frac{mh}{A(d_2 - d_1)t}$$

[1] J. G. Henderson, "Metallurgical Dictionary."
[2] D. Tabor, "The Hardness of Metals."

2e-4. Effect of High Pressure on the Specific Volume of Solids. Tables 2e-18 to 2e-22 present data on the change of specific volume of certain solids as a result of the imposition of very high pressure. The general reference in this field is P. W. Bridgman, "The Physics of High Pressure," G. Bell & Sons, Ltd, London, 1949.

Specific references are attached to each table.

TABLE 2e-18. VOLUME OF SOLID HELIUM AT 0°K*

Pressure, kg/cm²	Volume, ml/mole	Compressibility $(1/v)(\partial v/\partial p)_T$
52	19.0	184×10^{-5}
91	18.0	135
141	17.0	100
207	16.0	73
305	15.0	52
475	14.0	37
718	13.0	25
1,105	12.0	16
1,715	11.0	12
2,240	10.5	10

* J. S. Dugdale and F. E. Simon, *Proc. Roy. Soc. (London)* **218,** 291 (1953).

TABLE 2e-19. FRACTIONAL CHANGE OF VOLUME AT 25°C OF RELATIVELY INCOMPRESSIBLE METALS*

Pressure, kg/cm²	$\Delta V/V_0$						
	W	Pt	Fe	Cu	Ag	Au	Al
5,000	0.00155	0.00176	0.00289	0.00353	0.00473	0.00281	0.00668
10,000	0.00309	0.00351	0.00575	0.00696	0.00938	0.00558	0.01312
15,000	0.00475	0.00526	0.00856	0.01039	0.01385	0.00831	0.01932
20,000	0.00634	0.00701	0.01133	0.01370	0.01820	0.01101	0.02520
25,000	0.00797	0.00877	0.01407	0.01695	0.02236	0.01367	0.03090
30,000	0.00959	0.01048	0.01676	0.02010	0.02619	0.01626	0.03642

* P. W. Bridgman, *Proc. Am. Acad. Arts Sci.* **77,** 187 (1949).

TABLE 2e-20. RELATIVE VOLUMES OF VARIOUS SOLIDS AT 25°C*

Pressure, kg/cm²	Lucite	Cellulose acetate	Bakelite	Hard rubber	Nylon 6–10	Teflon	Orthoclase
1	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
2,500	0.9633	0.9532	0.9760	0.9684	0.9615	0.9473	
5,000	0.9329	0.9216	0.9562	0.9390	0.9345	0.9153	
10,000	0.8903	0.8811	0.9240	0.8955	0.8940	0.8547	0.9829
15,000	0.8613	0.8514	0.8978	0.8655	0.8652	0.8306	
20,000	0.8329	0.8283	0.8765	0.8427	0.8430	0.8125	0.9667
30,000	0.8051	0.7035	0.8436	0.8083	0.8100	0.7857	0.9512
40,000	0.7816	0.7682	0.8188	0.7834	0.7861	0.7661	0.9366

Pressure, kg/cm²	Calcite	Garnet	Iodoform	Urea nitrate	Potassium phosphate	Potassium alum
1	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
5.000	......	......	0.9451	0.9628	0.9821	0.9718
10,000	0.9866	0.9929	0.9079	0.9358	0.9665	0.9486
15,000	tr.	......	0.8806	0.9145	0.9526	0.9296
20,000	0.9275	0.9862	0.8586	0.8966	0.9401	0.9131
30,000	0.9113	0.9800	0.8241	0.8669	0.9183	0.8843
40,000	0.8981	0.9743	0.7966	0.8431	0.9004	0.8607

* P. W. Bridgman, *Proc. Am. Acad. Arts Sci.* **76,** 71 (1948).

TABLE 2e-21. RELATIVE VOLUMES OF SOME OF THE MORE COMPRESSIBLE ELEMENTS, SALTS, AND OTHER SOLIDS AT 25°C*

In Tables 2e-21 and 2e-22 the symbol tr denotes a phase transition

Pressure, kg/cm²	Li	Na	K	Rb	Cs	Ca	Sr	Ba	C
1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
10,000	0.928	0.889	0.814	0.802	0.761	0.942	0.925	0.914 tr	
20,000	0.874	0.816	0.723	0.708	0.656 tr	0.897	0.878 tr	0.841 tr	
30,000	0.833	0.770	0.668	0.652	0.571	0.861	0.828	0.789	0.940
40,000	0.801	0.737	0.628	0.612	0.521 tr	0.832	0.791	0.747	0.929
50,000	0.773	0.708	0.595	0.578	0.431	0.805	0.761	0.712 tr	0.919
60,000	0.748	0.683	0.568	0.551	0.409	0.780 tr	0.734 tr	0.682	0.911
70,000	0.727	0.661	0.546	0.528	0.392	0.748	0.702	0.639	0.903
80,000	0.707	0.641	0.528	0.507	0.381	0.732	0.683	0.618	0.896
90,000	0.689	0.623	0.513	0.489	0.375	0.716	0.665	0.598	0.890
100,000	0.672	0.606	0.500	0.473	0.368	0.702	0.648	0.580	0.885

* P. W. Bridgman, *Proc. Am. Acad. Arts Sci.* **76**, 55, 71 (1948); **74**, 425 (1942).

TABLE 2e-22. RELATIVE VOLUMES OF SOLIDS AT 25°C*

Pressure, kg/cm²	Mg	Sn	Pb	Bi	S	NaCl	NaI	CsCl	CsI
1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
10,000	.....	0.982	0.978	0.972	0.917	0.962	0.944	0.952	0.935
20,000	.....	0.966	0.959	0.948 tr	0.869	0.932	0.902	0.914	0.887
30,000	0.935	0.951	0.941	0.842	0.837	0.907	0.868	0.882	0.849
40,000	0.919	0.936	0.925	0.826 tr	0.812	0.885	0.840	0.856	0.818
50,000	0.904	0.923	0.901	0.808	0.792	0.865	0.816	0.834	0.792
60,000	0.890	0.909	0.898	0.795 tr	0.775	0.848	0.795	0.816	0.770
70,000	0.878	0.897	0.885	0.778	0.760	0.832	0.777	0.801	0.751
80,000	0.866	0.886	0.874	0.768	0.747	0.817	0.761	0.788	0.734
90,000	0.856	0.875	0.864	0.760 tr	0.736	0.803	0.747	0.777	0.719
100,000	0.847	0.864	0.855	0.739	0.726	0.790	0.734	0.767	0.706

Pressure, kg/cm²	$NaNO_3$	PbS	PbTe	Quartz crystal	Quartz glass	Pyrex glass
1	1.000	1.000	1.000	1.000	1.000	1.000
10,000	0.966	0.980	0.978	0.976	0.970	0.969
20,000	0.938	0.962 tr	0.961	0.955	0.939	0.938
30,000	0.914	0.928	0.939	0.939	0.909	0.907
40,000	0.893	0.918	0.930 tr	0.926	0.885	0.885
50,000	0.873	0.909	0.884	0.914	0.864	0.867
60,000	0.846 tr	0.900	0.869	0.902	0.847	0.851
70,000	0.833	0.892	0.855	0.892	0.832	0.838
80,000	0.820	0.886	0.842	0.883	0.819	0.827
90,000	0.809	0.881	0.831	0.875	0.808	0.817
100,000	0.799	0.876	0.820	0.868	0.798	0.809

*P. W. Bridgman, *Proc. Am. Acad. Arts Sci.* **76**, 55, 71 (1948); **74**, 425 (1942).