TEI-822

MOLAR VOLUMES AND DENSITIES OF MINERALS

By Richard A. Robie and Philip M. Bethke

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July 1962

Report TEI-822

This report is preliminary and has not been edited for conformity with Geological Survey format.

* This work was supported in part by the Division of Reactor Development, U. S. Atomic Energy Commission.

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MOLAR VOLUMES AND DENSITIES OF MINERALS

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These tables present critically chosen "best values" for the density and molar volume of selected mineral compounds. No attempt was made to be all-inclusive; rather we have tried to present data for chemically and physically well-defined phases for which the molar volume and/or density was known to the order of 0.2 percent.

Data are included for several materials not known as minerals but for which the data are necessary for the calculation of partial molar volumes of intermediate members of a solid solution. For similar reasons we have also included a few values of hypothetical phases (e.g. FeS wurtzite and sphalerite structures, and CdS rock salt structure) based on the extrapolation of measured cell dimensions from incomplete solid solutions. These theoretical phases are so indicated in the tables. The majority of the data included are for pure synthetic phases for which unit cell parameters or densities have been determined with an accuracy of 0.1 percent or better. In some instances, where the mineral deviates from the stoichiometric composition, either by substitutional or omission solid solution, one or more values are given for materials of known composition as noted in the Formula column.

For several substances, measured densities having equal or greater accuracy than the X-ray data are available. For these compounds the molar volume was calculated from (1), and the uncertainty listed with the density.

Molar volumes were calculated from measured densities by the relation:

$$V = \frac{M}{\rho} \qquad (1.)$$

where M is the formula weight in grams and ρ is the density in grams cm^{-3}, or from the unit cell dimensions,

$$V = \frac{(\text{unit cell volume in } cm^3)\ (\text{Avogadro's number})}{(\text{number of formulas})/(\text{unit cell})} \qquad (2.)$$

Formulas for the volumes of various shaped unit cells are given in Barrett (1952).

Substances of trigonal symmetry are denoted by the symbol hex-R to distinguish them from materials of truly hexagonal symmetry. The cell volume and number of formula weights listed for these compounds are however given for the larger hexagonal cell.

Substances denoted by an asterisk indicate the data were obtained from natural mineral specimens whose composition may have deviated slightly from the listed composition. Densities given for these minerals were calculated using the formula weight for the stoichiometric phase.

The formula weights are based on the International Atomic Weights for 1957 (Wichers, 1958). Avogadro's number used for these tables is $(6.02322 \pm .00016) \times 10^{23}$ particles $mole^{-1}$ which is the physical value of Cohen, Crowe, and DuMond (1957) converted to the chemical scale, using the conversion factor $1.00027 \pm .000005$ of these authors. Temperatures for which the volumes and density apply are given in the second column from the right. Molar volumes for gases refer to the real gas at one atmosphere pressure. The letter r indicates that the measurements were made at an unspecified room temperature. This may be taken as 25°±5°C. Due to a lack of adequate thermal expansion data, no attempt was made to reduce all the data to the common reference temperature, 25°C. The uncertainties given for the molar volumes include an estimate of the precision, the reproducibility between different investigators and in some cases slight deviations from stoichiometry. Although the uncertainties are listed only for the molar volumes, it must be understood that an equal percentage uncertainty is associated with the cell volume and the density.

We wish to acknowledge the considerable help rendered in the preparation of these tables by our colleagues at the U. S. Geological Survey, particularly Mrs. Martha S. Toulmin who aided greatly in compiling and checking the unit cell parameters of the sulfides and related minerals and Jerry L. Edwards who checked the majority of the non-sulfide data and prepared the bibliography.

References

Barrett, Structure of Metals, McGraw-Hill Book Co., New York, 1952.

Wichers, J. Am. Chem. Soc. 80, 4121, 1958.

Cohen, Crowe, and DuMond, Fundamental Constants of Physics, Interscience Pub., New York, 1957.

ELEMENTS

Formula	Name	Formula Weight grams	Crystal System	Cell Volume $10^{-24}cm^3$	Z	Molar Volume cm^3	Density grams cm^{-3}	Temp °C	Ref.
Ag	Silver	107.880	cub	68.22_7	4	10.274 ±.005	10.500	25	139
Au	Gold	197.0	cub	67.84_7	4	10.216 ±.005	19.283	25	139
C *	Diamond	12.011	cub	45.380	8	3.4167 ±.0005	3.5154	25	126
C *	Graphite	12.011	hex	35.189	4	5.299 ±.002	2.267	15	98
Cu	Copper	63.54	cub	47.24_2	4	7.114 ±.004	8.932	25	139
Fe	α-Iron	55.85	cub	23.55_1	2	7.093 ±.004	7.874	25	142
Ni	Nickel	58.71	cub	43.75_6	4	6.589 ±.005	8.911	25	139
Pt	Platinum	195.09	cub	60.37_9	4	9.092 ±.005	21.457	25	139
S	α-Sulfur	32.066	orth	$3299._4$	128	15.53 ±.02	2.065	25	147
S	β-Sulfur	32.066	mon	$1315._3$	48	16.50 ±.04	1.943	103	35
Pb	Lead	207.2	cub	121.32	4	18.269 ±.005	11.342	25	139
Sn	β-Tin	118.70	tet	108.18	2	16.29 ±.01	7.286	26	73
Sb	Antimony	121.76	hex-R	180.52	6	18.18 ±.02	6.697	26	141
As	Arsenic	74.91	hex-R	129.14	6	12.96 ±.05	5.778	26	141
Bi	Bismuth	209.00	hex-R	212.29	6	21.31 ±.01	9.807	26	141
Se	Selenium	78.96	hex-R	81.793	3	16.42 ±.02	4.808	26	137
Te	Tellurium	127.61	hex-R	101.99	3	20.48 ±.02	6.231	25	139
Zn	Zinc	65.38	hex-R	30.427	2	9.164 ±.005	7.135	25	139

SULFIDES, TELLURIDES, SELENIDES, AND ARSENIDES

Formula	Name	Formula Weight grams	Crystal System	Cell Volume $10^{-24} cm^3$	Z	Molar Volume cm^3	Density grams cm^{-3}	Temp. °C	Ref.
β-$Ni_3Pb_2S_2$ *	Shandite	651.682	hex	367.7_6	3	73.8 ±.1	8.827	r	71, 107
Au_2Bi	Maldonite	603.00	cub	503.9_8	8	37.94 ±.01	15.892	r	75
Ag_2S I	Hi-Argentite	247.826	cub	246.3_7	4	37.1 ±.2	6.680	600	32
Ag_2S II	Argentite	247.826	cub	115.50	2	34.8 ±.1	7.125	189	32
Ag_2S III	Acanthite	247.826	orth	227.08	4	34.2 ±.2	7.254	r	32, 148
Ag_2Se	Hi-Naumannite	294.72	cub	124.48	2	37.5 ±.2	7.862	170	113
Ag_2Te I		343.37	cub	158.6	2	44.6 ±.2	7.702	825	113
Ag_2Te II		343.37	cub	285.5		43.0 ±.1	7.986	250	113
Ag_2Te III *	Hessite	343.37	mon	271.4	4	40.86 ±.20	8.405	r	49
Cu_2S I *	Hi-Digenite	159.146	cub	187.6	4	28.26 ±.10	5.632	465	31,
Cu_2S II *	Hi-Chalcocite	159.146	hex	97.16		27.51 ±.06	5.786	152	31,
Cu_2S III *	Chalcocite	159.146	orth	4379.5	96	27.48 ±.01	5.792	r	31,
$Cu_{1.79}S$ (Cu rich side)	Digenite	145.803	pseudo-cubic	172.7_6	4	26.01_5 ±.01	5.605	25	116
$Cu_{1.77}S$ (S rich side)	Digenite	144.532	pseudo-cubic	171.34	4	25.80 ±.01	5.602	25	31, 116
Cu_2Se	Berzelianite	206.04	cub	200.2	4	30.15 ±.15	6.835	170	113
$Ag_{1.55}Cu_{0.45}S$ I		227.873	cub	228.1_0	4	34.35 ±.10	6.634	300	32
$Ag_{1.55}Cu_{0.45}S$ II		227.873	cub	123.3_3	2	33.83 ±.10	6.736	116	32
$Ag_{1.55}Cu_{0.45}S$ III	Jalpaite	227.873	tet	884.30	16	33.29 ±.03	6.845	r	32
$Ag_{0.93}Cu_{1.07}S$ I		200.382	cub	211.8	4	31.90 ±.10	6.282	196	32
$Ag_{0.93}Cu_{1.07}S$ II		200.382	hex	105.4	2	31.73 ±.10	6.315	100	32

SULFIDES, TELLURIDES, SELENIDES, AND ARSENIDES

Formula	Name	Formula Weight grams	Crystal System	Cell Volume 10^{-24} cm^3	Z	Molar Volume cm^3	Density grams cm^{-3}	Temp. °C	Ref.
$Ag_{0.93}Cu_{1.07}S$ III	Stromeyerite	200.382	orth	214.8	4	32.35 ±.03	6.194	r	32
AgCuSe	Eucairite	248.40	orth	527.1	10	31.7 ±.6	7.824	r	47
Ag_3AuTe_2 *	Petzite	775.86	cub	1118.4	8	84.2 ±.2	9.214	r	48
Cu_3Se_2 *	Umangite	348.54	tet	175.3	2	52.8 ±.2	6.604	r	9, 38
Ni_3S_2	Heazlewoodite	240.262	hex	204.0	3	40.95 ±.02	5.867	r	79, 84
Cu_5FeS_4 *	Hi-Bornite	501.814	cub	166.4	1	100.2 ±.3	5.008	240	94
Cu_5FeS_4 *	Metastable Bornite	501.814	cub	1309.3	8	98.6 ±.3	5.090	r	94
Cu_5FeS_4 *	Lo-Bornite	501.814	tet	2618.6	16	98.6 ±.3	5.090	r	94
$Ni_{11}As_8$	Maucherite	1245.09	tet	1029.4	4	155.0 ±.1	8.033	r	172
$(Fe, Ni)_9S_8$	Pentlandite								
$Fe_{5.25}Ni_{3.75}S_8$		769.902	cub	1059.96	4	159.6 ±.3	4.824	r	85
$Fe_{3.75}Ni_{5.25}S_8$		774.194	cub	1028.8	4	154.9 ±.3	4.998	r	85
PtS	Cooperite	227.156	tet	73.563	2	22.15 ±.01	10.25_3	r	10, 59
CaS	Oldhamite	72.146	cub	184.687	4	27.72 ±.05	2.602	r	145, 65, 111
PbS	Galena	239.276	cub	209.16	4	31.495 ±.010	7.597	r	11, 140, 160
PbSe	Clausthalite	286.17	cub	229.84	4	34.609 ±.010	8.269	r	11
PbTe	Altaite	334.82	cub	269.66	4	40.606 ±.020	8.246	r	10
MnS	Alabandite	87.006	cub	142.52	4	21.460 ±.010	4.054	r	129, 10
MnS	sphalerite structure	87.006	cub	176.65	4	26.600 ±.010	3.271	r	127
MnS	wurtzite structure	87.006	hex	88.952	2	26.79 ±.01	3.248	r	132
CdS	Greenockite	144.476	hex	99.407	2	29.94 ±.01	4.826	r	132

SULFIDES, TELLURIDES, SELENIDES, AND ARSENIDES

Formula	Name	Formula Weight grams	Crystal System	Cell Volume 10^{-24} cm^3	Z	Molar Volume cm^3	Density grams cm^{-3}	Temp. °C	Ref.
CdS	Hawleyite	144.476	cub	198.46	4	29.88 ±.01	4.834	r	52, 157, 10
CdS (hypothetical)	NaCl structure	144.476	cub	167.83	4	25.27 ±.01	5.717	r	11
ZnS	Sphalerite	97.446	cub	158.279	4	23.834 ±.008	4.088$_5$	r	11, 127, 130, 131
ZnS	Wurtzite	97.446	hex	79.190	2	23.85 ±.01	4.086	r	130, 132
ZnSe	Stilleite	144.34	cub	182.14	4	27.427 ±.008	5.263	r	11, 57
ZnTe		192.99	cub	227.20	4	34.212 ±.010	5.641	r	10
HgS	Cinnabar	232.676	hex	141.55	3	28.419 ±.010	8.187	r	10, 142
HgS	Metacinnabar	232.676	cub	200.38	4	30.173 ±.010	7.711	r	10, 142
HgSe	Tiemannite	279.57	cub	225.34	4	33.932 ±.015	8.239	r	10, 145
HgTe	Coloradoite	328.22	cub	269.59	4	40.594 ±.010	8.085	r	10
FeS (hypothetical)	sphalerite structure	87.916	cub	161.43	4	24.309 ±.010	3.617	r	127, 131
FeS (hypothetical)	wurtzite structure	87.916	hex	82.38	2	24.810 ±.010	3.544	r	132
CoS (hypothetical)	sphalerite structure	91.006	cub	152.18	4	22.916 ±.010	3.971	r	66
CdSe	Cadmoselite	191.37	hex	112.00	2	33.731 ±.015	5.673	r	10
CdTe		240.020	cub	272.16	4	40.982 ±.020	5.857	r	10
$CuFeS_2$	Chalcopyrite								
$CuFeS_{1.90}$		180.315	tet	292.96	4	44.11 ±.05	4.088	r	11, 10
$CuFe_2S_3$ *	Cubanite	271.438	orth	447.5	4	67.39 ±.20	4.028	r	20
$AgFe_2S_3$ *	Sternbergite	317.778	orth	974.8	8	73.39 ±.20	4.330	r	106
$AgFe_2S_3$ *	Argentopyrite	317.778	orth	491.2	4	73.97 ±.20	4.296	r	97

SULFIDES, TELLURIDES, SELENIDES, AND ARSENIDES

Formula	Name	Formula Weight grams	Crystal System	Cell Volume 10^{-24} cm^3	Z	Molar Volume cm^3	Density grams cm^{-3}	Temp.	Ref.
NiAs	Niccolite	113.62	hex	57.07	2	17.186 ±.020	6.611	r	172
NiSb	Breithauptite	180.47	hex	69.37	2	20.893 ±.030	8.639	r	70
CuS	Covellite	95.606	hex	203.48	6	20.427 ±.020	4.680	r	142
CuSe	Klockmannite	142.50	hex	3014.8	78	23.257 ±.020	6.128	r	37, 150
SnS	Herzenbergite	150.776	orth	192.66	4	29.010 ±.020	5.197	r	95
$PbSnS_2$	Teallite	390.042	orth	199.24	2	60.002 ±.040	6.500	r	95
AsS *	Realgar	106.976	mon	791.6	16	29.82 ±.10	3.59	r	16
NiS	Millerite	90.776	hex	252.41	3	16.891 ±.008	5.374	r	10, 149, 79, 84
Sb_2S_3	Stibnite	339.718	orth	487.54	4	73.414 ±.05	4.696	25	143
Bi_2S_3	Bismuthinite	514.198	orth	501.59	4	75.529 ±.07	6.808	26	142
Bi_2Te_3	Tellurobismuthite	800.83	hex	507.32	3	101.86 ±.10	7.862	r	45, 161
As_2S_3 *	Orpiment	246.018	mon	468.3	4	70.52 ±.20	3.49	r	19
Co_3S_4	Linnaeite	305.084	cub	830.85	8	62.55 ±.05	4.877	r	87
Ni_3S_4	Polydymite	304.394	cub	851.97	8	64.14 ±.01	4.746	r	79
$FeNi_2S_4$	Violarite	301.534	cub	847.66	8	63.82 ±.05	4.725	r	86
$FeCr_2S_4$	Daubreeite	288.134	cub	989.83	8	74.52 ±.07	3.866	r	83
FeS_2	Pyrite	120.082	cub	159.000	4	23.942 ±.004	5.016	r	129, 82, 56
FeS	Troilite	87.916	hex	60.31	2	18.18 ±.01	4.835	r	155

SULFIDES, TELLURIDES, SELENIDES, AND ARSENIDES

Formula	Name	Formula Weight grams	Crystal System	Cell Volume 10^{-24} cm^3	Z	Molar Volume cm^3	Density grams cm^{-3}	Temp. °C	Ref.
FeS_2 *	Marcasite	120.082	orth	81.622	2	24.58 ±.02	4.885	25	128, 17
$FeSe_2$	Ferroselite	213.77	orth	97.538	2	29.97 ±.05	7.22	r	62, 9
$FeTe_2$	Frohbergite	311.07	orth	127.62	2	38.44 ±.07	8.092	r	60
CoS_2	Cattierite	123.072	cub	169.57	4	25.53 ±.04	4.820	r	87
$CoSe_2$	Trogtalite	216.86	cub	201.106	4	30.28 ±.01	7.162	r	23
NiS_2	Vaesite	122.842	cub	184.045	4	27.700 ±.005	4.435	r	10, 79, 84
$NiSe_2$		216.63	cub	211.75	4	31.88 ±.01	6.795	20	61
$NiTe_2$	Melonite	313.93	hex	68.81	1	41.4 ±.1	7.58	r	151
MnS_2	Hauerite	119.072	cub	227.18	4	34.202 ±.006	3.481	28	128
$PtAs_2$ *	Sperrylite	344.91	cub	212.56	4	32.00 ±.05	10.778	r	56, 152
RuS_2	Laurite	165.232	cub	175.6	4	26.4 ±.2	6.26	r	8, 9, 30, 101
$NiAs_2$	Rammelsbergite	208.53	orth	97.675	2	29.42 ±.04	7.088	26	116, 148, 172
$NiAs_2$	Pararammelsbergite	208.53	orth	382.4	8	28.8 ±.1	7.24	r	78, 105
$FeAs_2$	Loellingite	205.67	orth	91.36	2	27.51 ±.02	7.476	26	116, 148
$CoAs_2$	Co-safflorite	208.76	mon	92.706	2	27.92 ±.02	7.477	26	116, 148
$(Co, Fe)As_2$	Safflorite								
$Co_{0.5}Fe_{0.5}As_2$		207.72	orth	92.23	2	27.78 ±.06	7.477	26	116, 148
MoS_2	Molybdenite	160.082	hex	106.35	2	32.03 ±.01	4.998	26	143
WS_2	Tungstenite	247.992	hex	106.50	2	32.07 ±.02	7.733	26	146
FeAsS *	Arsenopyrite	162.826	tri	175.49	4	26.42 ±.05	6.163	r	93
FeSbS *	Gudmundite	209.676	mon	399.1	8	30.05 ±.1	6.978	r	18
(Co,Fe)AsS *	Glaucodot	164.87	orth	1063.	24	26.7 ±.2	6.17	r	9

SULFIDES, TELLURIDES, SELENIDES, AND ARSENIDES

Formula	Name	Formula Weight grams	Crystal System	Cell Volume $10^{-24}cm^3$	Z	Molar Volume cm^3	Density grams cm^{-3}	Temp. °C	Ref.
CoAsS *	Cobaltite	165.916	cub	175.6	4	26.4 ±.4	6.28	r	9
NiAsS	Gersdorfite	165.686	cub	184.51	4	27.78 ±.01	5.964	26	149
$FeAs_{3-x}$	Fe-Skutterudite								
$FeAs_{2.95}$ (hypothetical)		276.83	cub	547.62	8	41.231 ±.010	6.714	r	115
$CoAs_{3-x}$	Co-Skutterudite								
$CoAs_{2.95}$		279.92	cub	552.57	8	41.604 ±.010	6.728	r	115
$NiAs_{3-x}$ (hypothetical)	Ni-Skutterudite								
$NiAs_{2.95}$		279.69	cub	578.01	8	43.518 ±.010	6.427	r	115
$Cu_{12}As_4S_{13}$	Tennantite	1478.987	cub	1058.1	2	31.87 ±.08	4.641	26	129
$Cu_{12}Sb_4S_{13}$	Tetrahedrite	1666.378	cub	1101.3	2	33.17 ±.07	5.024	26	129
Cu_3AsS_4	Enargite	393.794	orth	293.0	2	88.2_5 ±.1	4.46	26	129
Cu_3AsS_4	Luzonite	393.794	tet	292.0	2	87.9_5 ±.1	4.48	26	129, 51
Cu_3SbS_4	Famatinite	440.644	tet	312.2	2	94.0_2 ±.1	4.69	26	129, 51
Ag_3AsS_3	Proustite	494.748	hex	880.89	6	88.4 ±.1	5.59_7	26	155
Ag_3SbS_3	Pyrargyrite	541.598	hex	922.18	6	92.5 ±.3	5.85_5	26	155

OXIDES AND HYDROXIDES

Formula	Name	Formula Weight grams	Crystal System	Cell Volume $10^{-24}cm^3$	Z	Molar Volume cm^3	Density grams cm^{-3}	Temp °C	Ref.
Al_2O_3	Corundum	101.96	hex-R	254.7_0	6	25.57 ±.01	3.988	26	140
AlO(OH)	Boehmite	59.988	orth	129.7_5	4	19.54 ±.02	3.070	26	141
$HAlO_2$	Diaspore	59.988	orth	117.9_6	4	17.76 ±.03	3.377	25	22,141
$Al(OH)_3$	Gibbsite	78.004	mon	424.49	8	31.96 ±.06	2.441	r	35
As_2O_3	Arsenolite	197.82	cub	1358.0	16	51.12 ±.03	3.869	25	139
BeO	Bromellite	25.013	hex	27.61_2	2	8.315 ±.005	3.008	26	139
CO		28.011				22408. ± 15		0	5
CO_2		44.011				22263. ± 20		0	5
CaO	Lime	56.08	cub	111.3_2	4	16.76 ±.01	3.345	27	139,15
$Ca(OH)_2$	Portlandite	74.096	hex-R	54.88_3	1	33.06 ±.04	2.241	27	139,15
CdO		128.41	cub	103.5_1	4	15.59 ±.01	8.238	27	140
CeO_2	Cerianite	172.13	cub	158.4_3	4	23.86 ±.02	7.216	26	139
CoO		74.94	cub	77.31	4	11.64 ±.01	6.438	26	147
Cr_2O_3	Eskolaite	152.02	hex-R	288.7_2	6	28.98 ±.05	5.245	26	143
CuO	Tenorite	79.54	mon	81.16_2	4	12.22 ±.02	6.508	26	139
Cu_2O	Cuprite	143.08	cub	77.83_3	2	23.44 ±.02	6.104	26	140
$Fe_{.953}O$	Wüstite	69.225	cub	79.99_6	4	12.05 ±.06	5.745	r	162
Fe_2O_3	Hematite	159.70	hex-R	301.6_2	6	30.28 ±.02	5.274	25	63
Fe_3O_4	Magnetite	231.55	cub	591.4_3	8	44.53 ±.02	5.200	25	1,154
α-FeO(OH) *	Goethite	88.858	orth	138.2_7	4	20.82 ±.03	4.268	r	104
γ-FeO(OH) *	Lepidocrocite	88.858	orth	148.5	4	22.37 ±.08	3.972	r	104
H_2O	Water	18.016				18.069 ±.003	.9971	25	5
H_2O	Ice	18.016	hex	130.41	4	19.637 ±.010	.9174	0	80

OXIDES AND HYDROXIDES

Formula	Name	Formula Weight grams	Crystal System	Cell Volume $10^{-24}cm^3$	Z	Molar Volume cm^3	Density grams cm^{-3}	Temp °C	Ref.
HfO_2	Hafnia	210.50	mon	138.30	4	20.82 ±.01	10.108	r	2
HgO	Montroydite	216.61	orth	128.3_1	4	19.32 ±.02	11.211	25	147
MgO	Periclase	40.32	cub	74.70_9	4	11.25 ±.01	3.584	25	126, 139
$Mg(OH)_2$	Brucite	58.336	hex-R	40.90_3	1	24.64 ±.03	2.368	26	144
MnO	Manganosite	70.94	cub	87.81_2	4	13.22 ±.01	5.365	26	143, 53
MnO_2	Pyrolusite	86.94	tet	55.16	2	16.61 ±.06	5.233	r	138
Mn_2O_3	Bixbyite	157.88	cub	833.5_0	16	31.38 ±.03	5.032	25	147
Mn_3O_4	Hausmanite	228.82	tet	623.6	4	46.96 ±.08	4.873	r	158
MoO_3	Molybdite	143.95	orth	202.9_8	4	30.72 ±.02	4.686	26	141
NiO	Bunsenite	74.71	cub	72.87_7	4	10.97 ±.01	6.808	26	139
PbO	Litharge	223.21	tet	79.40_2	2	23.91 ±.02	9.334	27	140
PbO	Massicot	223.21	orth	153.7_6	4	23.15 ±.02	9.641	27	140
SO_2		64.066				21894. ± 15		0	5
Sb_2O_3	Senarmontite	291.52	cub	$1386._9$	16	52.21 ±.03	5.583	26	141
Sb_2O_3	Valentinite	291.52	orth	332.1_3	4	50.01 ±.06	5.829	25	148
SiO_2 *	α-Quartz	60.09	hex-R	113.01_3	3	22.690 ±.005	2.648	25	46
SiO_2	α-Cristobalite	60.09	tet	170.9_5	4	25.74 ±.02	2.334	25	148
SiO_2	β-Cristobalite	60.09	cub	363.7_2	8	27.38 ±.02	2.194	405	134
SiO_2	α-Tridymite	60.09	hex			26.53 ±.20	2.265	r	43
SiO_2	β-Tridymite	60.09	hex	182.0_8	4	27.42 ±.03	2.192	405	134
SiO_2 *	Coesite	60.09	mon	548.3_7	16	20.64 ±.05	2.911	25	128
SiO_2 *	Stishovite	60.09	tet	46.541	2	14.016 ±.01	4.287	r	24
SiO_2	β-Quartz	60.09	hex-R	118.15	3	23.72 ±.01	2.533	575	174
SiO_2	Keatite	60.09	tet	479.2	12	24.05 ±.30	2.498	r	124

OXIDES AND HYDROXIDES

Formula	Name	Formula Weight grams	Crystal System	Cell Volume $10^{-24}cm^3$	Z	Molar Volume cm^3	Density grams cm^{-3}	Temp °C	Ref.
SnO_2	Cassiterite	150.70	tet	71.56_6	2	21.55 ±.02	6.992	26	139
TeO_2 *	Tellurite	159.61	orth	368.6_1	8	27.75 ±.02	5.751	25	147
TeO_2	Para-tellurite	159.61	tet	176.0_9	4	26.52 ±.02	6.020	25	148
ThO_2	Thorianite	264.05	cub	175.16_9	4	26.38 ±.01	10.011	25	126,139
TiO_2	Rutile	79.90	tet	62.42_8	2	18.80 ±.02	4.250	25	139,29
TiO_2	Anatase	79.90	tet	136.1	4	20.49 ±.03	3.899	26	139,29
TiO_2 *	Brookite	79.90	orth	257.4_2	8	19.38 ±.07	4.123	r	35
UO_2	Uraninite	270.07	cub	163.5_1	4	24.62 ±.01	10.969	26	140
ZnO	Zincite	81.38	hex	47.61_5	2	14.34 ±.01	5.675	25	67
ZrO_2	Baddeleyite	123.22	mon	140.4_5	4	21.15 ±.06	5.826	r	2

SPINELS, ALUMINATES AND TITINATES

Formula	Name	Formula Weight grams	Crystal System	Cell Volume $10^{-24}cm^3$	Z	Molar Volume cm^3	Density grams cm^{-3}	Temp °C	Ref.
$BeAl_2O_4$	Chrysoberyl	126.973	orth	227.9	4	34.32 ±.06	3.699	25	147
$MgAl_2O_4$	Spinel	142.28	cub	527.5	8	39.72 ±.03	3.582	26	140
$FeAl_2O_4$	Hercynite	173.81	cub	542.1	8	40.82 ±.06	4.258	25	156
$MnAl_2O_4$	Galaxite	172.90	cub	563.2	8	42.40 ±.05	4.078	25	147
$ZnAl_2O_4$	Gahnite	183.34	cub	528.5	8	39.79 ±.04	4.608	26	140
$FeFe_2O_4$	Magnetite	231.55	cub	590.8	8	44.50 ±.03	5.206	25	1,154
$MnFe_2O_4$	Jacobsite	230.64	cub	613.9	8	46.22 ±.07	4.990	25	147
$NiFe_2O_4$	Trevorite	234.41	cub	579.9	8	43.66 ±.08	5.369	25	148
$MgCr_2O_4$	Picrochromite	192.34	cub	578.6	8	43.57 ±.06	4.415	26	147
$CaTiO_3$	Perovskite	135.98	orth	223.33	4	33.63 ±.03	4.043	r	76
$FeTiO_3$ *	Ilmenite	151.75	hex-R	315.9	6	31.71 ±.05	4.786	r	102, 35
$MgTiO_3$	Geikielite	120.22	hex-R	307.4	6	30.86 ±.03	3.895	26	143

HALIDES

Formula	Name	Formula Weight grams	Crystal System	Cell Volume $10^{-24}cm^3$	Z	Molar Volume cm^3	Density grams cm^{-3}	Temp °C	Ref
NaCl	Halite	58.448	cub	179.42	4	27.018 ±.007	2.163	25	140
KCl	Sylvite	74.557	cub	249.23	4	37.528 ±.007	1.987	25	139
NaF	Villiaumite	41.991	cub	99.52	4	14.99 ±.01	2.802	25	139
AgBr	Bromyrite	187.796	cub	192.5_5	4	28.99 ±.01	6.477	26	142
AgCl	Cerargyrite	143.337	cub	170.8_7	4	25.73 ±.01	5.571	26	142
AgI	Iodyrite	234.79	hex	158.3_7	2	41.31 ±.02	5.684	25	146
CaF_2	Fluorite	78.08	cub	163.0_0	4	24.54 ±.01	3.181	25	139, 4
MgF_2	Sellaite	62.32	tet	65.23	2	19.64 ±.02	3.172	27	142, 36
HgCl	Calomel	236.067	tet	218.8	4	32.94 ±.02	7.166	25	139
Na_3AlF_6 *	Cryolite	209.953	mon	$235._3$	2	70.86 ±.25	2.963	r	103
HCl		36.465				22246. ± 20		0	5
$NaMgF_3$	Neighborite	104.311	orth	226.5_4	4	34.11 ±.02	3.058	18	25
AgI	Miersite	234.79	cub	273.99	4	41.26 ±.08	5.690	r	159

CARBONATES AND NITRATES

Formula	Name	Formula Weight grams	Crystal System	Cell Volume $10^{-24}cm^3$	Z	Molar Volume cm^3	Density grams cm^{-3}	Temp °C	Ref.
$CaCO_3$	Calcite	100.091	hex-R	367.9_6	6	36.94 ±.02	2.712	26	58
$CaMg(CO_3)_2$ *	Dolomite	184.422	hex-R	320.5_1	3	64.35 ±.04	2.866	26 ±3	58
$CdCO_3$	Otavite	172.421	hex-R	341.7_2	6	34.30 ±.02	5.015	26 ±3	58
$CoCO_3$	Cobalticalcite	118.951	hex-R	281.0_8	6	28.22 ±.01	4.215	26 ±3	58
$FeCO_3$	Siderite	115.861	hex-R	292.6_8	6	29.38 ±.02	3.944	26 ±3	58
$MgCO_3$	Magnesite	84.331	hex-R	279.1_3	6	28.02 ±.01	3.009	26 ±3	58
$Mg_3Ca(CO_3)_4$ *	Huntite	353.084	hex-R	612.1_5	3	122.90 ±.30	2.873	26 ±3	58
$MnCO_3$	Rhodochrosite	114.951	hex-R	309.5_7	6	31.08 ±.01	3.698	26 ±3	58
$NiCO_3$		118.721	hex-R	269.5_1	6	27.06 ±.02	4.387	26 ±3	58
$ZnCO_3$	Smithsonite	125.391	hex-R	281.6_9	6	28.28 ±.01	4.434	26 ±3	58
$BaCO_3$	Witherite	197.371	orth	304.2_4	4	45.81 ±.04	4.308	26	140
$CaCO_3$	Aragonite	100.091	orth	226.8_5	4	34.16 ±.02	2.930	26	141
$PbCO_3$	Cerussite	267.221	orth	269.6_5	4	40.60 ±.03	6.581	26	140
$SrCO_3$	Strontianite	147.641	orth	259.0_7	4	39.01 ±.03	3.785	26	141
$Cu_2(OH)_2CO_3$	Malachite	221.107	mon	364.3_5	4	54.86 ±.05	4.025	25	148
$Cu_3(OH)_2(CO_3)_2$	Azurite	344.358	mon	302.2_3	2	91.02 ±.07	3.784	25	148
KNO_3	Niter	101.108	orth	319.0_7	4	48.04 ±.05	2.104	26	141
$NaNO_3$	Soda Niter	84.999	hex-R	374.5_7	6	37.60 ±.02	2.260	25	144
$BaMg(CO_3)_2$ *	Norsethite	281.70	hex-R	365.6	3	73.39 ±.10	3.838	r	96
$CaCO_3$	Vaterite	100.091	hex-R	375.8_1	6	37.73 ±.05	2.653	r	88
$Cu_2(NO_3)(OH)_3$	Gerhardite	240.112	orth	455.0_1	4	68.52 ±.08	3.504	r	108

SULFATES AND BORATES

Formula	Name	Formula Weight grams	Crystal System	Cell Volume $10^{-24}cm^3$	Z	Molar Volume cm^3	Density grams cm^{-3}	Temp °C	Ref.
$BaSO_4$	Barite	233.426	orth	346.0_5	4	52.11 ± .05	4.480	26	141
$CaSO_4$	Anhydrite	136.146	orth	305.0_9	4	45.94 ± .05	2.963	26	142
$PbSO_4$	Anglesite	303.276	orth	318.1_5	4	47.96 ± .05	6.324	25	141
$SrSO_4$	Celestite	183.696	orth	307.1_7	4	46.25 ± .05	3.972	26	140
$ZnSO_4$	Zinkosite	161.446	orth	276.1_0	4	41.58 ± .05	3.883	25	145
K_2SO_4	Arcanite	174.266	orth	435.0_3	4	65.51 ± .07	2.660	25	141
Na_2SO_4	Thenardite	142.048	orth	708.4_7	8	53.34 ± .06	2.663	25	140
$CaSO_4 \cdot 2H_2O$ *	Gypsum	172.178	mon	(493.5)	4	74.31 ± .16	2.317 ± .005	r	103
$MgSO_4 \cdot 7H_2O$	Epsomite	246.498	orth	(975.2)	4	146.85 ± .50	1.677 ± .004	25	103
$Na_2SO_4 \cdot 10H_2O$	Mirabilite	322.208	mon	$1459._9$	4	219.83 ± .40	1.466	24	117
$CuSO_4 \cdot 5H_2O$	Chalcanthite	249.686	tri	(362.2)	2	109.08 ± .20	2.289 .004	r	42, 103
$Cu_4SO_4(OH)_6$ *	Brochantite	452.274	mon	754.4	4	113.60 ± 1.15	3.981	r	35
$Na_2B_4O_5(OH)_4 \cdot 8H_2O$	Borax	381.422	mon	$1478._8$	4	222.68 ± .40	1.713	r	91
$CaB_3O_4(OH)_3 \cdot H_2O$ *	Colemanite	205.580	mon	564.2_7	4	84.97 ± .08	2.419	r	26
$K_2Ca(SO_4)_2 \cdot H_2O$	Syngenite	328.428	mon	424.2_7	2	127.77 ± .15	2.570	r	7

PHOSPHATES, MOLYBDATES AND TUNGSTATES

Formula	Name	Formula Weight grams	Crystal System	Cell Volume $10^{-24}cm^3$	Z	Molar Volume cm^3	Density grams cm^{-3}	Temp °C	Ref.
$AlPO_4$	Berlinite	121.955	hex-R	232.0	3	46.59 ±.05	2.618	25	148
$Ca_5(PO_4)_3OH$	Hydroxylapatite	502.333	hex	530.1_4	2	159.66 ±.40	3.146	r	110, 89
YPO_4	Xenotime	183.895	tet	283.6	4	42.70 ±.07	4.307	25	146
$CaMoO_4$	Powellite	200.03	tet	312.2	4	47.01 ±.08	4.255	25	144
$PbMoO_4$	Wulfenite	367.16	tet	357.7	4	53.87 ±.06	6.816	25	145
$CaWO_4$	Scheelite	287.94	tet	312.5	4	47.05 ±.04	6.119	25	144
$PbWO_4$	Stolzite	455.07	tet	359.3	4	54.11 ±.04	8.411	25	145
$FeWO_4$	Ferberite	303.71	mon	134.1_6	2	40.40 ±.06	7.517	r	122
$MnWO_4$	Huebnerite	302.80	mon	139.0_6	2	41.88 ±.06	7.230	r	122
$Fe_{.5}Mn_{.5}WO_4$	Wolframite	303.255	mon	136.6_3	2	41.15 ±.06	7.370	r	122
$Ca_5(PO_4)_3F$	Fluorapatite	504.325	hex	523.3	2	157.60 ±.40	3.200	r	89
$Ca_5(PO_4)_3Cl$	Chlorapatite	520.782	hex	544.2	2	163.88 ±.50	3.178	r	89

SILICATES

Formula	Name	Formula Weight grams	Crystal System	Cell Volume $10^{-24}cm^3$	Z	Molar Volume cm^3	Density grams cm^{-3}	Temp °C	Ref.
Al_2SiO_5 *	Andalusite	162.05	orth	342.2_6	4	51.54 ± .01	3.144	25	133
Al_2SiO_5 *	Kyanite	162.05	tri	292.9_0	4	44.11 ± .02	3.674	25	133
Al_2SiO_5 *	Sillimanite	162.05	orth	331.4_2	4	49.91 ± .02	3.247	25	133
$Ca_3Al_2Si_3O_{12}$	Grossularite	450.47	cub	1664.4_3	8	125.32 ± .04	3.595	25	125
$Ca_3Cr_2Si_3O_{12}$	Uvarovite	500.53	cub	1727.5_7	8	129.98 ± .06	3.851	26	148
$Ca_3Fe_2Si_3O_{12}$	Andradite	508.21	cub	1748.8_2	8	131.67 ± .04	3.860	25	125
$Fe_3Al_2Si_3O_{12}$	Almandite	497.78	cub	1531.2_1	8	115.28 ± .04	4.318	25	125
$Mg_3Al_2Si_3O_{12}$	Pyrope	403.19	cub	1504.6_6	8	113.29 ± .04	3.559	25	125
$Mn_3Al_2Si_3O_{12}$	Spessartite	495.05	cub	1569.3_9	8	118.16 ± .04	4.190	25	125
$KAl_2(AlSi_3O_{10})(OH)_2$ *	Muscovite	398.326	mon(2M)	933.3_9	4	140.55 ± .50	2.834	27	169, 44
$KMg_3(AlSi_3O_{10})(OH)_2$ *	Phlogopite	417.326	mon(1M)	496.9_5	2	149.66 ±1.0	2.788	r	168
$KMg_3(AlSi_3O_{10})F_2$	Fluor-Phlogopite	421.31	mon(1M)	486.0_7	2	146.38 ± .50	2.878	r	77
$KFe_3(AlSi_3O_{10})(OH)_2$	Annite	511.916	mon(1M)	512.4_0	2	154.32 ±1.0	3.317	26	165
$Al_2Si_4O_{10}(OH)_2$ *	Pyrophyllite	360.336	mon	841.0	4	126.6 ± .50	2.845	r	64
$Mg_3Si_4O_{10}(OH)_2$ *	Talc	379.336	mon	903.7	4	136.7 ± .30	2.788	r	64, 175
γ-Ca_2SiO_4 *	Lime Olivine	172.25	orth	389.3_4	4	58.63 ± .35	2.938	r	100
Fe_2SiO_4	Fayalite	203.79	orth	308.1_1	4	46.39 ± .08	4.393	25	170
Mg_2SiO_4	Forsterite	140.73	orth	290.8_1	4	43.79 ± .03	3.214	25	129
Mn_2SiO_4 *	Tephroite	201.97	orth	322.8_7	4	48.62 ± .10	4.154	r	72
$CaMgSiO_4$ *	Monticellite	156.49	orth	341.1_3	4	51.37 ± .15	3.046	r	120
$CaFeSiO_4$	Kirschsteinite	188.02	orth	350.3_9	4	52.76 ± .10	3.564	r	120

SILICATES

Formula	Name	Formula Weight grams	Crystal System	Cell Volume $10^{-24}cm^3$	Z	Molar Volume cm^3	Density $grams\ cm^{-3}$	Temp °C	Ref.
β-Ca_2SiO_4 *	Larnite	172.25	mon	342.7	4	51.60 ± .40	3.338	r	90
Be_2SiO_4 *	Phenacite	110.116	hex-R	$1111._6$	18	37.20 ± .06	2.960	25	146
Zn_2SiO_4	Willemite	222.85	hex-R	$1566._6$	18	52.42 ± .13	4.251	25	145
$ThSiO_4$	Thorite	324.14	tet	322.7_6	4	48.60 ± .10	6.669	r	50
$ZrSiO_4$ *	Zircon	183.31	tet	260.7_6	4	39.27 ± .08	4.668	25	142
$USiO_4$	Coffinite	330.16	tet	306.4_5	4	46.14 ± .10	7.155	r	50
$CaSiO_3$ *	Wollastonite	116.17	tri	397.8	6	39.94 ± .08	2.909	r	166, 21
$CaSiO_3$ *	Parawollastonite	116.17	mon	790.3	12	39.67 ± .08	2.928	r	153
$CaSiO_3$ *	Pseudowollastonite	116.17	tri (mon)	$1597._0$	24	40.08 ± .08	2.898	r	166, 74
$MgSiO_3$ *	Clino-Enstatite	100.41	mon	417.9_8	8	31.47 ± .07	3.190	r	92
$MgSiO_3$ *	Enstatite	100.41	orth	834.0_4	16	31.40 ± .07	3.198 ± .007	26	69, 144
$MnSiO_3$ *	Rhodonite	131.03	tri	(586.4)	10	35.32 ± .30	3.71 ± .03	r	
$CaMg(SiO_3)_2$	Diopside	216.58	mon	438.9_7	4	66.10 ± .10	3.277	r	167, 121
$CaFe(SiO_3)_2$ *	Hedenbergite	248.11	mon	(438.1)	4	65.97 ± .30	3.55 ± .01	r	68
$NaAlSi_2O_6$ *	Jadeite	202.151	mon	(405.0)	4	60.98 ± .40	3.315 ± .020	r	3, 164, 171
$Ca_2Mg_5Si_8O_{22}(OH)_2$ *	Tremolite	812.496	mon	906.3_4	2	272.95 ± .90	2.976	r	163, 173
$Ca_2Mg_5Si_8O_{22}F_2$	Fluor-Tremolite	816.48	mon	898.0_4	2	270.45 ± .40	3.019	20	28
$Ca_2Fe_5Si_8O_{22}(OH)_2$ *	Fe-Tremolite	970.146	mon	(947.3)	2	285.3 ± .8	3.400 ± .009	r	163
$Na_2Mg_3Fe_2Si_8O_{22}(OH)_2$	Mg-Riebeckite	841.376	mon	908.6	2	273.6 ± .8	3.075	r	39
$Na_2Mg_3Al_2Si_8O_{22}(OH)_2$	Glaucophane	783.636	mon	895.4	2	269.7 ± .8	2.906	r	40

SILICATES

Formula	Name	Formula Weight grams	Crystal System	Cell Volume $10^{-24} cm^3$	Z	Molar Volume cm^3	Density grams cm^{-3}	Temp °C	Ref.
$Mg_7Si_8O_{22}(OH)_2$ *	Anthophyllite	780.976	orth	(1820.)	4	274.0 ±3.5	2.850 ±.050	r	112
$Fe_7Si_8O_{22}(OH)_2$ *	Grunerite	1001.684	mon	(924.7)	2	278.5 ±1.0	3.597 ±.010	r	13
$Be_3Al_2(Si_6O_{18})$ *	Beryl	537.539	hex	675.9_8	2	203.58 ± .50	2.640	25	147
$Mg_2Al_3(AlSi_5O_{18})$	Hi-Cordierite	585.01	hex	773.0_3	2	232.81 ± .30	2.513	r	123
$Mg_2Al_3(AlSi_5O_{18})$	Lo-Cordierite	585.01	orth	$1550._7$	4	233.50 ± .30	2.505	r	123
$CaAl_2Si_2O_8$	Anorthite	278.22	tri	(668.9_4)	4	100.73 ± .15	2.762 ±.004	r	27, 54, 135
$NaAlSi_3O_8$	Albite	262.241	tri	(665.4_9)	4	100.21 ± .19	2.617 ±.005	r	135, 81
$NaAlSi_3O_8$	Analbite	262.241	tri	668.2_8	4	100.63 ± .15	2.606 ±.004	r	135, 81
$KAlSi_3O_8$ *	Microcline	278.35	tri	721.8_3	4	108.69 ± .20	2.561	r	81, 55
$KAlSi_3O_8$	Sanidine	278.35	mon	723.7	4	108.98 ± .20	2.554	r	34
$CaTiSiO_5$ *	Sphene	196.07	mon	369.9	4	55.70 ± .30	3.520	r	35
$Zn_4(OH)_2Si_2O_7.H_2O$ *	Hemimorphite	481.732	hex-R	459.3_6	2	138.34 ± .30	3.482	25	140
$(AlF)_2SiO_4$ *	Topaz	184.05	orth	343.1	4	51.66 ± .10	3.563	26	149
	Tourmaline								
$NaMg_3Al_6B_3Si_6O_{27}(OH)_4$	Dravite	958.863	hex-R	$1577._9$	3	316.80 ±1.00	3.027	r	114
$CaMg_4Al_5B_3Si_6O_{27}(OH)_4$	Uvite	973.292	hex-R	$1566._3$	3	314.47 ±1.00	3.095	r	114
$NaAlSi_2O_6.H_2O$	Analcite	220.167	cub	2590.0	16	97.50 ± .10	2.258	r	119
$NaAlSiO_4$	Nepheline	142.061	hex	719.5	8	54.17 ± .15	2.623	r	33

SILICATES

Formula	Name	Formula Weight grams	Crystal System	Cell Volume $10^{-24} cm^3$	Z	Molar Volume cm^3	Density grams cm^{-3}	Temp	Ref.
$Al_2Si_2O_5(OH)_4$ *	Dickite	258.172	mon	659.5_1	4	99.31 +.30	2.600	r	99
$Ca_2MgSi_2O_7$	Akermanite	272.68	tet	308.2_2	2	92.82 ±.15	2.938	r	6, 41
$Ca_2Al_2Si_2O_7$	Gehlenite	274.21	tet	299.6_7	2	90.25 ±.15	3.038	r	6, 41
$CaAl_2Si_2O_7(OH)_2 \cdot H_2O$	Lawsonite	314.252	orth	672.9_6	4	101.33 ±.15	3.101	r	109
$KAlSiO_4$	Kalsilite	158.17	hex	351.4_0	2	60.43 ±.06	2.617	r	136
$KAlSi_2O_6$ *	Leucite	218.26				88.01 ±.15	2.480	r	12
$KAlSi_3O_8$ *	Orthoclase	278.35	mon	(724.6)	4	109.11 ±.30	2.551 ±.008	r	12
$NaAlSiO_4$	Lo-Carnegieite	142.061				56.53 ±.10	2.513 ±.005	21	14
$3Al_2O_3 \cdot 2\ SiO_2$	Mullite	426.06	orth	167.5_7	7.5	134.57 ±.30	3.166	r	176
$2Al_2O_3 \cdot SiO_2$	Mullite	264.01	orth	168.37	6/5	84.51 ±.15	3.124	r	176, 118

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