U.S. Department of the Interior Geological Survey

Feasibility Study of
Data for Nuclear-Waste Disposal--Thermodynamic Properties
of Basalt, Granite, Shale, and Tuff

by

Gilpin R. Robinson, Jr., Constance M. Schafer, and John L. Haas, Jr.

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ABSTRACT

A compilation is presented of the available experimental data on the thermodynamic properties of 66 mineral phases that are commonly present in some of the rock types proposed as nuclear-waste storage candidates: 1) granite, 2) tuff, 3) shale, and 4) basalt. A summary of the chemistry and mineralogy of each rock type is given. A procedure to evaluate an internally consistent set of thermodynamic properties for minerals from the compiled experimental data is presented.

We conclude that sufficient reliable data exist to evaluate the thermodynamic properties of most of these mineral phases. These data are summarized in Table 2 and cited in detail in Appendix 2. Future efforts will be focused on deriving the properties of the end-member components of mineral phases that form solid solutions. Where experimental data are lacking or insufficient, the properties of heat capacity, volume thermal expansion, and volume compressibility can be estimated with an accuracy of a few percent. The greatest uncertainties and evaluation difficulties are foreseen for mineral phases having variable water content (zeolites, some mineral hydrates, some clays).

1. Introduction

The thermal and chemical evolution of a potential nuclear-waste repository must be known and understood before an intelligent decision can be made regarding radioactive-waste storage. A properly evaluated set of thermodynamic data can provide some of the needed information. This report presents a procedure to evaluate an internally consistent set of thermodynamic data for minerals and contains a tabulation of experimental data which may be used in this evaluation. Experimental data pertinent to mineral phases in 1) granitic, 2) tuffaceous, 3) shale, and 4) basaltic rock types are presented. An important feature of the evaluation procedure is the identification of inconsistent and erroneous data in the set of experimental data under consideration.

The report is divided into three sections. The first section briefly summarizes the chemical and physical character of the proposed repository rock types and identifies for each rock type:

1. a generalized chemical system describing the rock type,
2. the major mineral constituents,
3. the minor mineral constituents, and
4. the common alteration phases.

The second section is a summary of available experimental data on heat capacity, relative enthalpy, entropy, enthalpy of formation, enthalpy of reaction, Gibbs energy of reaction, chemical potential, molar volume, volume expansivity, and volume compressibility for the mineral phases of interest.

The third section presents the research proposal to generate an evaluated set of thermodynamic data for minerals. The evaluation will involve additional information for phases not tabulated here to provide an extensive, internally consistent, and reliable data base.

2. Summary of rock-type chemistry and mineralogy

2.1. Granite and other crystalline igneous rocks

Granitic crystalline igneous rocks occur as large, relatively homogeneous bodies which consist primarily of a granular aggregate of feldspar minerals and quartz. Grain size typically ranges between 1 mm to a few cm. The model chemical system is Na_2O-K_2O-CaO-(FeO)-(Fe_2O_3)-Al_2O_3-SiO_2-H_2O. Oxide components in parentheses are of less importance than the components not in parentheses. The minerals and their chemical formulas are given below. A typical analysis, including the norm and mode, is given on Table 1.

a. Major mineral constituents

The major minerals, as cited above, are quartz and the feldspars. They generally account for as much as 95 percent of the mineral volume. The formulas are as follows:

Quartz - SiO_2
Plagioclase feldspar - approximately Ano 20:Alb 80[1]
    Albite - $NaAlSi_3O_8$
    Anorthite - $CaAl_2Si_2O_8$
K-feldspar (microcline) - $KAlSi_3O_8$

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[1] Ano 20:Alb 80 signifies a composition of 20 percent anorthite and 80 percent albite of GFW (gram formula weight = molar) units in the feldspar. The three-character abbreviations for end-member mineral components are defined in Appendix 1. This notation style is used throughout the description of rock types.

Table 1. Representative rock compositions

Oxide wt. %	Granite[a]	Tuff[b]	Basalt[c]	Shale[d]
Chemical composition				
SiO_2	73.60	66.0	53.8	58.10
TiO_2	0.18	0.55	2.0	0.65
Al_2O_3	13.84	15.4	13.9	15.40
Fe_2O_3	0.63	2.6	2.6	4.02
FeO	1.43	2.0	9.3	2.45
MnO	0.04	0.1	0.2	
MgO	0.29	1.3	4.1	2.44
CaO	1.34	3.2	7.9	3.11
Na_2O	3.74	3.5	3.0	1.30
K_2O	4.27	4.3	1.5	3.24
H_2O	0.17	0.88	1.2	5.00
P_2O_5	0.02	0.22	0.4	0.17
Misc.		0.13[e]		4.07[f]
TOTAL	99.68	99.96	99.9	99.95
Norm (wt. %)(calculated from chemical composition)				
Quartz	31.20	20.1	3.9	
K-feldspar	25.38	25.7	8.9	
Albite	31.44	30.8	25.2	
Anorthite	6.95	13.4	20.0	

Table 1. Continued

	Granite[a]	Tuff[b]		Basalt[c]	Shale[d]	
Diopside				13.9		
Wollastonite		0.6				
Enstatite		3.2				
Ferrosilite		0.8				
Hypersthene	2.55			15.3		
Enstatite						
Ferrosilite						
Ilmenite	0.30	1.0		3.8		
Magnetite	0.93	3.9		3.7		
Apatite		0.5		0.9		
TOTAL	98.75	100.00		98.6		
Mode (measured) (volume %)						
Quartz	33.0	2.2	phenocrysts		Quartz	30.8
K-feldspar	32	1.3			Feldspar	4.5
Plagioclase	34	35				
Biotite	2	5.4			Fe-oxides	<0.5
Amphibole (hornblende)	1	<1			Carbonates	3.6
Magnetite		1.8			Organic matter	1
Orthopyroxene	0.5			<5		
Clinopyroxene		1.5		<5	Clays	59.9[g]
Olivine				<5		

Table 1. Continued

	Granite[a]	Tuff[b]	Basalt[c]	Shale[d]
Matrix		52[h]	>90[i]	
An content of Plagioclase (mole %)	21	36	63	
TOTAL	102.5	100.2	100.0	100.39

[a] Rubidoux Granite, California, sample E1-167, Larsen, 1948, GSA Mem. 29.

[b] Snowshoe Mtn. Quartz Latite, Colorado, sample S-56A, Ratte and Steven, 1967, USGS Prof. Paper 524-H.

[c] Average Yakima basalt (analysis b, p. 593), Columbia River Plateau, Washington-Oregon, Waters, 1961, AJS, 259, 583-611.

[d] Average shale, Shaw and Weaver, 1965, J. Sed. Pet., 35, 213-222.

[e] CO_2

[f] CO_2+SO_3+C

[g] Clays include: illite and mixed-layer clays, kaolinite, and chlorite (listed in order of decreasing abundance).

[h] Matrix comprises: 1) glass + alteration products in welded tuff, 2) microcrystalline intergrowth of plagioclase and cristobalite in devitrified tuffs, and 3) clays + zeolite minerals in altered tuffs.

[i] Matrix comprises: intergrown microcrystalline clinopyroxene (pigeonite), orthopyproxene, and plagioclase with minor cristobalite (listed in order of decreasing abundance).

b. Minor mineral constituents

The minor constituents of granites account for less than 5 volume percent of the rock and include the following:

Muscovite - $KAl_3Si_3O_{10}(OH)_2$

Biotite - commonly annite

  Annite - $KFe_3AlSi_3O_{10}(OH)_2$

  Phlogopite - $KMg_3AlSi_3O_{10}(OH)_2$

Garnet - commonly almandine

  Almandine - $Fe_3Al_2Si_3O_{12}$

Magnetite - Fe_3O_4

Amphibole - commonly hornblende - $Na_xCa_2(Mg,Fe)_{5-2y}$ $Al_{x+4y}Si_{8-x-2y}O_{22}(OH)_2$

$x \approx 0\text{-}1,\ y \approx 0.5$

c. Alteration phases

Alteration generally takes place near fractures at depth or near the weathering surface during erosion. Rock bodies that have experienced thermal metamorphism may show pervasive alteration. Alteration phases, besides quartz and the feldspars, include the following minerals:

Epidote - Zoisite - $Ca_2FeAl_2Si_3O_{12}(OH)$ - $Ca_2Al_3Si_3O_{12}(OH)$

Clays

  Kaolinite - $Al_2Si_2O_5(OH)_4$

  Smectite - commonly montmorillonite - beidellite

    Alkali-free

    Montmorillonite - $Al_2Si_4O_{10}(OH)_2 \cdot nH_2O$

    Montmorillonite - $(1/2Ca,Na)_{0.33}(Al_{1.67},(Mg,Fe)_{0.33}$
    $Si_4O_{10}(OH)_2 \cdot nH_2O$

    Beidellite - $(1/2Ca,Na)_{0.33}(Al_2)(Al_{0.33},Si_{3.67})$
    $O_{10}(OH)_2 \cdot nH_2O$

    Nontronite - $(1/2Ca,Na)_{0.33}(Fe^{+3})(Al_{0.33},Si_{3.67})$
    $O_{10}(OH)_2 \cdot nH_2O$

    $n \leq 2$

Calcite - $CaCO_3$

2.2. Tuff

Tuff is an indurated (hardened by temperature, pressure, and/or chemical reaction) volcanic deposit, predominantly composed of volcanic ash (fragmental volcanic material having grain diameter less than 4 mm). The fragmental material may consist of:

1. quenched magma in the form of glass particles,
2. phenocrysts (crystals grown in the magma chamber), and
3. rock fragments.

Tuff occurs as sheetlike bodies surrounding volcanic centers, and deposits range from less than a meter to more than 1000 meters in thickness. Large tuff units commonly are formed from volcanic air-fall or avalanche deposits. The avalanche deposits may be welded from the heat present during deposition.

The bulk composition of large tuff sheets typically ranges between the compositions of quartz latite-dacite and rhyolite. A representative analysis, norm, and mode are given in Table 1. The typical ranges of silica content and phenocryst content in large tuff sheets are as follows:

Rhyolite ←---→ Quartz Latite-Dacite

75 wt. % SiO_2 ←---→ 62 wt. % SiO_2

0% phenocrysts ←---→ 50% phenocrysts (volume percent)

Tuffs can be categorized into several types, which occur as zones in large deposits (Smith, 1961, USGS Prof. Paper 354-F, 149-159, plate 20-D):

1. unwelded to partially welded zone
2. partially to completely welded zone

3. devitrified zone
4. altered zone.

The model chemical system is Na_2O-K_2O-CaO-(MgO)-(FeO)-(Fe_2O_3)-Al_2O_3-SiO_2-H_2O. Mineral constituents of tuffs consist of phenocryst and matrix phases.

a. Phenocrysts

The phenocrysts, which typically are 0-50 volume percent of tuffs, could be any one or more of the following:

Plagioclase feldspar - typically Ano 20:Alb 80 - Ano 50:Alb 50
    Albite - $NaAlSi_3O_8$
    Anorthite - $CaAl_2Si_2O_8$
K-feldspar (sanidine) - $KAlSi_3O_8$
Quartz - SiO_2
Biotite - typically annite
    Annite - $KFe_3AlSi_3O_{10}(OH)_2$
    Phlogopite - $KMg_3AlSi_3O_{10}(OH)_2$

b. Accessory phenocrysts

The accessory phenocrysts, which are typically less than 2 volume percent, may be one or more of the following:

Clinopyroxene - typically ferroaugite - approximately
Hed 41:Dio 27:Cts 19:Cen 13
    Hedenbergite - $CaFe(SiO_3)_2$
    Diopside - $CaMg(SiO_3)_2$
    Ca-Al Clinopyroxene- $CaAl_2SiO_6$
    Clinoenstatite - $MgSiO_3$

Clinoferrosilite - $FeSiO_3$
Orthopyroxene
Enstatite - $MgSiO_3$
Ferrosilite - $FeSiO_3$
Wollastonite - $CaSiO_3$
Amphibole - commonly hornblende - $Na_xCa_2(Mg,Fe)_{5-2y}Al_{x+4y}Si_{8-x-2y}O_{22}(OH)_2$
$x \approx 0\text{-}1,\ y \approx 0.5$
Fayalite - Fe_2SiO_4
Magnetite - Fe_3O_4
Ilmenite - $FeTiO_3$

c. Matrix

Typically the matrix varies from about 50 to 100 volume percent. It varies by zone:

1. In the unwelded to partially welded zone and the partially welded to completely welded zone, the typical matrix is glass or glass plus alteration products. Glass tends to hydrate with time. Unhydrated fresh glass typically has a water content of < 1 wt. percent H_2O, whereas hydrated glass typically has a water content of 2-4 percent. Porosity may be as great as 50 percent in the unwelded to partially welded zone.

2. In the devitrified zone, the typical matrix is a microcrystalline intergrowth of alkali feldspar (Na-K feldspar) and cristobalite (SiO_2).

3. In the altered zone, the matrix is typically clay (montmorillonite) and/or zeolite minerals replacing glass and, in some places, phenocrysts.

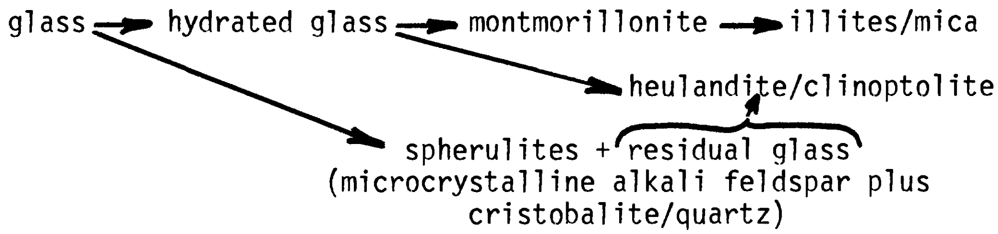
Alteration occurs more rapidly in hydrated glass than in unhydrated glass and hydration may be necessary to achieve alteration.

d. Alteration products

Typical alteration products are:

1. Clays
    a. Smectite - commonly montmorillonite - beidellite
        Alkali-free montmorillonite - $Al_2Si_4O_{10}(OH)_2 \cdot nH_2O$
        Montmorillonite - $(1/2Ca,Na)_{0.33}(Al_{1.67},(Mg,Fe)_{0.33})Si_4O_{10}(OH)_2 \cdot nH_2O$
        Beidellite - $(1/2Ca,Na)_{0.33}(Al_2)(Al_{0.33},Si_{3.67})O_{10}(OH)_2 \cdot nH_2O$
        Nontronite - $(1/2Ca,Na)_{0.33}(Fe_2^{+3})(Al_{0.33},Si_{3.67})O_{10}(OH)_2 \cdot nH_2O$
        $n \leqslant 2$
    b. Kaolinite/Halloysite/Dickite - $Al_2Si_2O_5(OH)_4$
2. Zeolites
    a. Clinoptolite - $(Na,K,Ca)_{2-3}Al_3(Al,Si)_2Si_{13}O_{36} \cdot 12H_2O$
        (generally an impure heulandite)
    b. Heulandite - $CaAl_2Si_7O_{18} \cdot 6H_2O$
    c. Analcite - $NaAlSi_2O_6 \cdot H_2O$
3. Miscellaneous
    a. Calcite - $CaCO_3$
    b. Illite - $(K,H_3O)_{x+y}(Al_{2-x}(Mg,Fe)_x)(Si_{4-y},Al_y)O_{10}(OH)_2 \cdot 1\text{-}x\text{-}y\text{-}zH_2O$ $\quad x+y+z \leqslant 1$

Observed alteration sequences are[2] :



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[2] Barrows, 1980, GSA Bull., 91, 199-210.

2.3. Flood basalt

Flood basalt occurs as sheets of rapidly cooled basaltic lava erupted from a volcanic center in continental basement. Individual sheets typically have great areal extent and range from less than 1 meter to 100 meters in thickness.

The model chemical system is $CaO\text{-}(Na_2O)\text{-}FeO\text{-}(Fe_2O_3)\text{-}MgO\text{-}Al_2O_3\text{-}SiO_2\text{-}(H_2O,CO_2)$. A typical analysis, norm, and mode are given on Table 1.

a. Major constituents

The major constituents consist of phenocrysts and matrix phases. Phenocrysts typically account for 0 to 10 percent of the rock volume, and matrix composes the remainder. Gas bubbles (vesicles) occur in some basalt units, usually near the top surface of the flow.

1. Phenocrysts usually are:
    - Olivine - typically For 90:Fay 10
        - Forsterite - Mg_2SiO_4
        - Fayalite - Fe_2SiO_4
    - Plagioclase - typically Ano 60:Alb 40
        - Anorthite - $CaAl_2Si_2O_8$
        - Albite - $NaAlSi_3O_8$
2. Matrix, which typically is a microcrystalline intergrowth of:
    - Clinopyroxene - typically pigeonite - approximately Cen 46:Cfs 38:Dio 9:Hed 7
        - Diopside - $CaMg(SiO_3)_2$
        - Hedenbergite - $CaFe(SiO_3)_2$

Clinoenstatite - $MgSiO_3$

Clinoferrosilite - $FeSiO_3$

Hypersthene - approximately Ens 60:Fes 40

Enstatite - $MgSiO_3$

Ferrosilite - $FeSiO_3$

Plagioclase

Anorthite - $CaAl_2Si_2O_8$

Albite - $NaAlSi_3O_8$

b. Alteration products

Alteration products typically occur in vesicles or along fractures and flow-unit contacts in basalts. The low- and intermediate-temperature alterations are temperature-induced responses to heated fluids moving through the rock, and most of the alteration phases require the addition of either water or carbon dioxide to the rock. The intermediate- and high-temperature alterations are a result of thermal metamorphism of the rock body. Basalts which have experienced thermal metamorphism may show pervasive alteration.

1. Low-temperature ($T < 250°C$) reactions typically produce the following minerals:

Calcite - $CaCO_3$

Dolomite - $CaMg(CO_3)_2$

Epidote - Zoisite - $Ca_2FeAl_2Si_3O_{12}(OH)$ - $Ca_2Al_3Si_3O_{12}(OH)$

Prehnite - $Ca_2Al_2Si_3O_{10}(OH)_2$

Lawsonite - $CaAl_2Si_2O_7(OH)_2 \cdot H_2O$

Zeolites

- Laumontite - $CaAl_2Si_4O_{12}\cdot 4H_2O$
- Heulandite - $CaAl_2Si_7O_{18}\cdot 6H_2O$
- Analcite - $NaAlSi_2O_6\cdot H_2O$
- Wairakite - $CaAl_2Si_4O_{12}\cdot 2H_2O$

2. Intermediate-temperature ($T \leq 375°C$) reactions typically produce the following minerals:

- Calcite - $CaCO_3$
- Dolomite - $CaMg(CO_3)_2$
- Albite - $NaAlSi_3O_8$
- Zoisite - $Ca_2Al_3Si_3O_{12}(OH)$
- Chlorite (Clinochlore) - $Mg_5Al_2Si_3O_{10}(OH)_4$
- Amphibole
  - Tremolite - $Ca_2Mg_5Si_8O_{22}(OH)_2$
  - Actinolite - $Ca_2Fe_5Si_8O_{22}(OH)_2$
  - Anthophyllite - $Mg_7Si_8O_{22}(OH)_2$

3. High-temperature ($T \geq 350°C$) reactions typically produce the following minerals:

- Amphibole - commonly hornblende - $Na_xCa_2(Mg,Fe)_{5-2y}Al_{x+4y}Si_{8-x-2y}O_{22}(OH)_2$

  $x \approx 0\text{-}1,\ y \approx 0.5$
- Garnet - typically almandine or grossular
  - Grossular - $Ca_3Al_2Si_3O_{12}$

Almandine - $Fe_3Al_2Si_3O_{12}$
Pyrope - $Mg_3Al_2Si_3O_{12}$
Clinopyroxene
Hedenbergite - $CaFe(SiO_3)_2$
Diopside - $CaMg(SiO_3)_2$
Ca-Al Clinopyroxene - $CaAl_2SiO_6$
Wollastonite - $CaSiO_3$
Orthopyroxene
Enstatite - $MgSiO_3$
Ferrosilite - $FeSiO_3$
Olivine
Forsterite - Mg_2SiO_4
Fayalite - Fe_2SiO_4
Spinel
Magnetite - Fe_3O_4

2.4. Shale

Shale is a rock composed of detrital particles having an average diameter less than 1/16 mm in which the clay fraction (grain size $<$ 1/256 mm) predominates over the silt fraction (grain size 1/16 - 1/256 mm). Detrital particles are fragmental material produced by the disintegration and weathering of rocks. Shales are an abundant rock type deposited in sedimentary basins and typically occur as tabular bodies having great areal extent.

The model chemical system is K_2O-MgO-(FeO)-(Fe_2O_3)-(Na_2O)-Al_2O_3-SiO_2-H_2O. A typical analysis and mode are given in Table 1.

a. Major constituents

The major constituents are as follows:

1. Clays
    - a. Smectite - commonly montmorillonite - beidellite

      Alkali-free montmorillonite - $Al_2Si_4O_{10}(OH)_2 \cdot nH_2O$

      Montmorillonite - $(1/2Ca,Na)_{0.33}(Al_{1.67},(Mg,Fe)_{0.33})Si_4O_{10}(OH)_2 \cdot nH_2O$

      Beidellite - $(1/2Ca,Na)_{0.33}(Al_2)(Al_{0.33},Si_{3.67})O_{10}(OH)_2 \cdot nH_2O$

      Nontronite - $(1/2Ca,Na)_{0.33}(Fe_2{}^{+3})(Al_{0.33},Si_{3.67})O_{10}(OH)_2 \cdot nH_2O$
    - b. Kaolinite/Halloysite/Dickite - $Al_2Si_2O_5(OH)_4$
    - c. Illite - $(K,H_3O)_{x+y}(Al_{2-x},(Mg,Fe)_x)(Si_{4-y},Al_y)O_{10}(OH)_2 \cdot 1\text{-}x\text{-}y\text{-}zH_2O \qquad x+y+z \leqslant 1$
    - d. Mixed-layer clay - interlayered mixture of illite - smectite
2. Muscovite - $KAl_3Si_3O_{10}(OH)_2$
3. Chlorite

   Clinochlore - $Mg_5Al_2Si_3O_{10}(OH)_4$
4. Quartz - SiO_2

b. Typical minor constituents

Typical minor constituents are as follows:

1. Plagioclase - typically Ano 0:Alb 100 - Ano 5:Alb 95

   Albite - $NaAlSi_3O_8$

   Anorthite - $CaAl_2Si_2O_8$

2. K-feldspar (Microcline) - $KAlSi_3O_8$
3. Carbonates
    - Calcite - $CaCO_3$
    - Dolomite - $CaMg(CO_3)_2$
    - Ankerite - $CaFe(CO_3)_2$
4. Oxides
    - Magnetite - Fe_3O_4
    - Hematite - Fe_2O_3
5. Organic matter
    - Carbon - C
6. Pyrite - FeS_2

3. Summary of available experimental data on the thermodynamic properties of minerals

Table 2 summarizes the experimental data on heat capacity (Cp), relative enthalpy (H_T-H_{298}), entropy (S), enthalpy of formation (H), enthalpy of reaction (H), Gibbs energy of reaction (G), molar volume (V), volume thermal expansion (dV/dT), and volume compressibility (dV/dP) available for the mineral phases of interest. The symbols in the above parentheses identify the type of data in Table 2. An X in the column under a data-type symbol indicates that experimental information is available on that thermodynamic property for the phase. If heat capacity or relative enthalpy data are available, the temperature range (above 298 K) of the measured data is given.

Indirect constraints on thermodynamic properties caused by the functional relationships among thermodynamic properties are not shown in the table. Measurement of Gibbs energy at different temperatures for a phase constrains the properties of enthalpy and entropy for the phase if the heat capacity is known. For example, no experimental calorimetric data on entropy or enthalpy exist for andradite; however, data on a series of phase equilibrium studies (Gibbs energy of reaction) and heat capacity are available and cover a sufficiently broad temperature range to constrain the properties of entropy and enthalpy.

Where data are lacking or insufficient, estimates of the thermodynamic properties are needed to evaluate the properties of the phase. For most phases only heat capacity, volume thermal expansion, and volume compressibility need to be estimated, and these properties may be estimated with an accuracy of a few percent by use of the technique described in section 4.2.a. For example, the heat capacity of hedenbergite will need to be estimated to evaluate the available phase equilibria data and derive entropy, enthalpy, and Gibbs energy properties.

Phases lacking data on heat capacity, entropy, and enthalpy and having only one measured value of Gibbs energy (epistilbite, heulandite, Na-montmorillonite, and stilbite in this compilation) need estimated values for heat capacity and entropy. Molar entropy also may be estimated by use of the techniques mentioned in section 4.2.b.

The information summarized on Table 2 indicates that we should be able to derive internally consistent thermodynamic properties for most of the tabulated phases. The symbols in the left-hand column of Table 2 identify the repository rock type commonly containing the mineral as a component.

Appendix 2 contains tables of the available experimental data listed by reference citation for each mineral phase in Table 2. These citations have been through a preliminary evaluation in that 1) we reviewed each citation to insure there were no obvious errors in experimental technique and 2) we determined that there was no obvious ambiguity in the identification of the phases.

We are aware of conflicts in the cited experimental data, but these cannot be resolved at this time. To resolve them, one must compare the conflicting data with theory and with other properties measured on the phase (or phases) in the data sets. This can be done best during the correlation procedure!

Table 2. Summary of available experimental data on thermodynamic properties of minerals

Rock type[a]	Mineral/phase	Formula	Cp (H_T-H_{298})	Cp (H_T-H_{298}) - range (T/K)	S	H	G	V	dV/dT	dV/dP
G,S,Ta,Ba	Albite - low	$NaAlSi_3O_8$	X	298 - 1373	X	X	X	X	X	X
G,Sa	Almandine	$Fe_3Al_2Si_3O_{12}$					X	X	X	X
G,T	Analbite	$NaAlSi_3O_8$	X	298 - 1000	X	X	X	X	X	
Ta,Ba	Analcite	$NaAlSi_2O_6 \cdot H_2O$	X	298 - 998	X	X	X	X		X
Sa	Andalusite	Al_2SiO_5	X	298 - 1600	X	X	X	X	X	X
Ba	Andradite	$Ca_3Fe_2Si_3O_{12}$	X	298 - 1100			X	X		
G,T,Sa	Annite	$KFe_3AlSi_3O_{10}(OH)_2$	X	335 - 700			X	X		
B	Anorthite	$CaAl_2Si_2O_8$	X	298 - 1673	X	X	X	X	X	
Ba	Anthophyllite	$Mg_7Si_8O_{22}(OH)_2$	X	350 - 1000		X	X	X		
Ba	Antigorite	$Mg_{48}Si_{34}O_{85}(OH)_{62}$	X	298 - 848	X		X	X		
Ba	Aragonite	$CaCO_3$	X	298 - 600	X	X	X	X	X	
Sa	Boehmite	$AlO(OH)$	X	298	X		X	X		
Ba	Brucite	$Mg(OH)_2$	X	298 - 699	X	X	X	X	X	
Ta,Ba,S	Calcite	$CaCO_3$	X	298 - 1200	X	X	X	X	X	X
B	Ca-Al Clinopyroxene	$CaAl_2SiO_6$	X	298 - 1000		X	X	X		
	Carbon dioxide	CO_2	X	298 - 6000	X	X		X	X	X
Ba	Chrysotile	$Mg_2Si_2O_5(OH)_4$	X	298	X	X	X	X		

Table 2. Continued

Rock type[a]	Mineral/phase	Formula	Cp (H_T-H_{298})	Cp (H_T-H_{298}) - range (T/K)	S	H	G	V	dV/dT	dV/dP
S,Ba	Clinochlore	$Mg_5Al_2Si_3O_{10}(OH)_4$					X	X		
B,T	Clinoenstatite	$MgSiO_3$	X	298 - 1800	X	X	X	X	X	
B,T	Clinoferrosilite	$FeSiO_3$					X	X		
	Corundum	Al_2O_3	X	298 - 6000	X	X	X	X	X	X
Ta	Cristobalite	SiO_2	X	298 - 3000	X	X	X	X	X	
Sa	Diaspore	$AlO(OH)$	X	298 - 509	X		X	X		
S	Dickite	$Al_2Si_2O_5(OH)_4$	X	298	X	X		X		
B,T	Diopside	$CaMg(SiO_3)_2$	X	298 - 1600	X	X	X	X	X	X
S,Ba,Ta	Dolomite	$CaMg(CO_3)_2$	X	298 - 800	X	X	X	X		
B,T	Enstatite	$MgSiO_3$				X	X	X	X	X
Ga,Ta,Ba,S	Epidote	$Ca_2FeAl_2Si_3O_{12}(OH)$	X	335 - 1100			X	X		
Ta,Ba	Epistilbite	$CaAl_2Si_6O_{16}\cdot 5H_2O$					X	X		
T,Ba	Fayalite	Fe_2SiO_4	X	298 - 1724	X	X	X	X	X	X
T,B	Ferrosilite	$FeSiO_3$					X	X		
B	Forsterite	Mg_2SiO_4	X	298 - 1808	X	X	X	X	X	X
Sa	Gibbsite	$Al(OH)_3$	X	298 - 480	X	X		X		
S	Graphite	C	X	298 - 6000	X			X	X	

Table 2. Continued

Rock type[a]	Mineral/phase	Formula	Cp (H_T-H_{298})	Cp (H_T-H_{298}) - range (T/K)	S	H	G	V	dV/dT	dV/dP
Ba,Sa	Grossular	$Ca_3Al_2Si_3O_{12}$	X	298 - 978	X	X	X	X	X	X
S	Halloysite	$Al_2Si_2O_5(OH)_4$	X	298	X	X				
B	Hedenbergite	$CaFe(SiO_3)_2$					X	X	X	X
Ba,Ta,Ga,S	Hematite	Fe_2O_3	X	298 - 1757	X		X	X	X	
Ta,Ba	Heulandite	$CaAl_2Si_7O_{18}\cdot 6H_2O$					X	X		
S	Illite	$(K,H_3O)_{x+y}(Mg,Fe)_xAl_{2-x+y}Si_{4-y}O_{10}(OH)_2\cdot$ $(1-x-y-z)H_2O$ $x+y+z \leq 1$	X	298 - 380	X					
S,Ta	Kaolinite	$Al_2Si_2O_5(OH)_4$	X	298 - 800	X	X	X	X		
Sa	Kyanite	Al_2SiO_5	X	298 - 1503	X	X	X	X	X	X
T,Ba	Laumontite	$CaAl_2Si_4O_{12}\cdot 4H_2O$					X	X		
Ta,Ba	Lawsonite	$CaAl_2Si_2O_7(OH)_2\cdot H_2O$	X	298	X	X	X	X		
Ta,Ba	Leonhardite	$Ca_2Al_4Si_8O_{24}\cdot 7H_2O$	X	298	X					
Ba	Magnesite	$MgCO_3$	X	298 - 743	X		X	X		
Ta,Ba,Ga,S	Magnesiocalcite	$(Ca,Mg)CO_3$					X	X		
G,S,T,B	Magnetite	Fe_3O_4	X	298 - 1825	X		X	X	X	
S	Margarite	$CaAl_4Si_2O_{10}(OH)_2$	X	298 - 1000	X		X	X		
S,G,T	Microcline	$KAlSi_3O_8$	X	298 - 1400	X	X		X		X

Table 2. Continued

Rock type[a]	Mineral/phase	Formula	Cp (H_T-H_{298})	Cp (H_T-H_{298}) - range (T/K)	S	H	G	V	dV/dT	dV/dP
G,S,Ta	Muscovite	$KAl_3Si_3O_{10}(OH)_2$	X	298 - 967	X	X	X	X		
S,Ta	Na-Beidellite	$Na_{.33}Al_2(Al_{.33}Si_{3.67})O_{10}(OH)_2$					X			
S	Paragonite	$NaAl_3Si_3O_{10}(OH)_2$	X	298 - 800	X		X	X		
B	Phlogopite	$KMg_3AlSi_3O_{10}(OH)_2$	X	335 - 1100			X	X	X	X
Ba,Ta	Prehnite	$Ca_2Al_2Si_3O_{10}(OH)_2$	X	298 - 800	X		X	X		
B,Ta,S,G	Pyrite	FeS_2	X	298 - 1000	X			X		
Ba	Pyrope	$Mg_3Al_2Si_3O_{12}$	X	298 - 1000	X	X	X	X	X	X
S,Ta	Pyrophyllite	$Al_2Si_4O_{10}(OH)_2$	X	298 - 680	X		X	X	X	
S,Ba	Pyrrhotite	$Fe_{1-x}S$	X	298 - 2000	X	X		X	X	
G,S,T	Quartz	SiO_2	X	298 - 2000	X	X	X	X	X	X
T,G	Sanidine	$KAlSi_3O_8$	X	298 - 1400	X	X	X	X		
	Steam	H_2O (gas)	X	398 - 6000	X	X	X	X	X	X
Ta,Ba	Stilbite	$CaAl_2Si_7O_{18}\cdot 7H_2O$					X	X		
Ba	Talc	$Mg_3Si_4O_{10}(OH)_2$	X	298 - 800	X	X	X	X	X	X
Ba	Tremolite	$Ca_2Mg_5Si_8O_{22}(OH)_2$	X	298 - 800	X	X	X	X	X	X
Ta,Ba	Wairakite	$CaAl_2Si_4O_{12}\cdot 2H_2O$					X	X		

Table 2. Continued

Rock type[a]	Mineral/phase	Formula	Cp (H_T-H_{298})	Cp (H_T-H_{298}) - range (T/K)	S	H	G	V	dV/dT	dV/dP
	Water	H_2O (liquid)	X	298 - 398	X	X	X	X	X	X
B	Wollastonite	$CaSiO_3$	X	298 - 1573	X	X	X	X	X	X
G,Ta,Ba,S	Zoisite	$Ca_2Al_3Si_3O_{12}(OH)$	X	298 - 730	X		X	X		

[a] Rock type typically containing the mineral phase as a component. Notation:

granite (G); altered granite (Ga)
tuff (T); altered tuff (Ta)
basalt (B); altered basalt (Ba)
shale (S); altered shale (Sa)

4. Research proposal

As part of the coordinated effort to produce evaluated data related to the disposal of nuclear waste, the National Center for the Thermodynamic Data of Minerals (at the U.S. Geological Survey, Reston, VA) will perform the following tasks:

1. Assemble a general data file on the chemical and mineralogical character of granitic, tuffaceous, basaltic, and shale rock types. These data include the following:

    a. chemical analysis of sample,

    b. mineralogical analysis of sample,

    c. experimental heat capacity or relative enthalpy of the sample, and

    d. experimental methods used in the studies.

2. Assemble all experimental data on the thermodynamic properties of the mineral components in the above-named rock groups. These data include the following:

    a. heat capacity of the mineral,

    b. relative enthalpy of the mineral,

    c. entropy data,

    d. reaction data that involve one or more minerals (examples of such data are phase equilibria studies, enthalpies of reaction, electromotive force measurements, or determination of equilibrium constants),

    e. molar volumes and changes in response to changes in temperature or pressure,

f. any algebraic functions developed in the studies, and

g. the experimental methods used in the studies.

3. Evaluate the assembled experimental data by simultaneous, weighted, least-squares regression analysis to provide an internally consistent set of thermodynamic properties for the mineral components of the above-named rock types.

4. Prepare compilations of the thermodynamic properties of these mineral components. The compilations include the following:

a. Tables of thermodynamic properties (heat capacity, relative enthalpy, entropy, Planck's function, enthalpy of formation, Gibbs energy of formation, molar volume, volume thermal expansion, and volume compressibility) for the mineral phases.

b. Standard errors of estimate for the tabulated thermodynamic properties.

c. Algebraic functions which describe these thermodynamic properties and the temperature/pressure range of the function's validity.

d. A summary of the data sources and experimental methods used in the evaluation.

4.1. Procedure

An internally consistent set of thermodynamic properties for minerals can be evaluated from a diverse body of experimental data by use of the procedures described by Haas and Fisher (1976, AJS, 276, 525-545). Experimental data on heat capacities, relative enthalpy, entropy, enthalpy of formation, enthalpy of reaction, Gibbs energy of reaction, chemical potential, electrochemical potential, molar volume, volume expansivity, and volume compressibility are weighted according to their precision of measurement and simultaneously fit to an equation-of-state obeying the functional relationships among thermodynamic properties. The following outline summarizes the evaluation procedure.

a. Literature search

(1) Review of literature for data that define the thermodynamic properties of mineral phases.

(2) Close scrutiny of each citation to determine:

(a) what was physically observed.

(b) with what precision was it observed.

(3) Data may be excluded from the evaluation for the following reasons:

(a) obvious error in measurement technique.

(b) ambiguity in the identification or characterization of the mineral phases involved in the study.

b. Refinement cycle

(1) Comparison of related data (heat capacity, relative enthalpy, entropy, enthalpy of formation, enthalpy of reaction, Gibbs energy of reaction, electrochemical potential) for phases in a chemical system using weighted, simultaneous, multiple, least-squares regression.

(a) Nonsignificant constants for each phase are identified by the fitting procedure and are eliminated from the general equation to avoid overfitting the data.

(b) Information sources inconsistent with the net of evaluated data are identified.

(2) Review of pertinent literature where data are found to be in disagreement.

(3) Removal of assumed or apparently erroneous data from the set of data being fit by the regression.

(4) Repeat of steps (1) through (3) until all discordant data have been identified and inconsistencies resolved.

c. Table preparation

Tables of thermodynamic properties are prepared for each mineral phase using the smoothing functions and variance-covariance matrix from the last execution of step b.(1), above.

This evaluation procedure offers two improvements over other techniques currently used to derive thermodynamic data from experimental data.

First, diverse experimental data covering different thermophysical properties, involving multiple phases, and measured over a broad range of physical and chemical conditions are evaluated simultaneously. Erroneous and incompatible data are readily identified by this procedure. The identification of incompatible data is valuable because it identifies data that need to be reevaluated and, perhaps, reinvestigated experimentally. After conflicts are resolved, the user has an internally consistent set of data.

Second, the experimental data are weighted in the fitting procedure according to their precision of measurement. The use of weighting constrains the fit toward the more precise observations and allows the simultaneous fitting of different properties that have large variations in magnitude. The evaluation procedure supplies the user a simultaneous least-squares fit of the weighted consistent data in the chemical system. An important feature of this procedure is the availability of confidence limits for the properties as a function of temperature and pressure.

4.2. Techniques to estimate thermodynamic properties where experimental data are lacking

Various techniques may be used to estimate thermodynamic properties of minerals with an accuracy of a few percent. Estimates of thermodynamic properties are needed for the relatively few mineral phases for which data are insufficient to evaluate the properties of the phase.

a. Heat capacity, volume thermal expansion, and volume compressibility

From existing experimental data on silicate minerals we can evaluate algebraic functions describing heat capacity (Cp) and relative volume (V/Vo) for Na_2O, K_2O, CaO, MgO, Al_2O_3 (octahedral coordination), Al_2O_3 tetrahedral coordination, FeO, Fe_2O_3 (octahedral coordination), Fe_2O_3 (tetrahedral coordination), SiO_2, H_2O (hydrate), H_2O (zeolite), and H_2O (hydroxyl) structural components for mineral phases. Where data are lacking, these thermodynamic properties may be estimated for other mineral phases by summation of the component properties in the proper proportions relative to the stoichiometry of the phase.

b. Entropy

Estimation functions relating the molar properties of entropy, volume, and mass have been prepared by Helgeson and others (1978, AJS, 278-A, 229) and Cantor (1977, Science, 198, 206-207) and can be used to estimate the molar entropy of a phase for which direct data are lacking.

c. Phases of variable composition - chemical potential and activity of mineral components

Many of the mineral phases considered in this evaluation have variable composition and can be considered solid solutions between end-member mineral components. Some of the available information on the mixing properties of mineral components is summarized in the tables in Appendix 2. Where possible, this information will be evaluated and presented in the final report. Understanding the thermodynamic consequences of solid solution among the feldspars (albite/analbite - anorthite, albite/analbite - microcline/sanidine), micas (muscovite - paragonite, annite - phlogophite), amphiboles, pyroxenes, garnets (almandine - pyrope - grossular), and clays (illite - mixed-layer clay) is critical to modeling reactions between these and other phases. However, we will be primarily concerned with evaluating the thermodynamic properties of the end-member components for the mineral phases.

Minerals that contain variable amounts of structural H_2O (for example, zeolites, some hydrates, some clays) present a problem in the evaluation because their compositions are frequently not known in phase equilibrium studies. Their compositions, as a function of pressure and temperature, may be approximated from a thermodynamic model for water in these crystal structures by evaluating the exchange reaction

$$H_2O \text{ xl,site A} \rightleftarrows [\ ] \text{ xl,site A} + H_2O \text{ v}$$

where xl and v designate the crystalline and vapor phases, respectively, and site A is a crystallographic site for water in the mineral. The mineral may have more than one crystallographic site for water. If X is defined as the mole fraction of site A filled by H_2O in the crystal, then

$$K = \frac{1-X_{xl,\text{site A}}}{X_{xl,\text{site A}}} .$$

$$\ln K + n_{H_2O}\left(\frac{G^\circ_{T,H_2O}}{RT} + \ln f_{H_2O}\right) + (P-P^\circ)\frac{\Delta V_{r,s}}{RT} = \frac{-\Delta H_r}{RT} + \frac{\Delta S_r}{R}$$

where G°_{T,H_2O} = standard state Gibbs energy of H_2O at temperature and reference pressure

f_{H_2O} = fugacity of H_2O

$\Delta V_{r,s}$ = molar volume change among the solid phases represented by the above exchange reaction

ΔH_r = standard molar enthalpy of the exchange reaction (assumed to be independent of temperature)

ΔS_r = standard molar entropy of the exchange reaction (assumed to be independent of temperature)

R = gas constant

n_{H_2O} = molar stoichiometric coefficient for H_2O in the exchange reaction

P = pressure

P° = reference pressure

T = temperature in K

This function is linear in $(\frac{1}{T})$ at constant pressure, and ΔH_r and ΔS_r for each crystallographic site may be evaluated from:

1. enthalpy-of-solution measurements of hydrated, partially hydrated, and dehydrated phases of known composition.

2. measurements of partial pressure of H_2O equilibrated with the phase of known composition as a function of temperature.

3. differential gravimetric analysis of the phase as a function of temperature under a controlled H_2O pressure.

Appendix 1. Mineral phases, formulas, and codes used in this-report

Code	Phases	Formula
Akt	Akermanite	$Ca_2MgSi_2O_7$
Alb	Albite, low	$NaAlSi_3O_8$
Alm	Almandine	$Fe_3Al_2Si_3O_{12}$
Ana	Analbite	$NaAlSi_3O_8$
Anl	Analcite	$NaAlSi_2O_6 \cdot H_2O$
And	Andalusite	Al_2SiO_5
Adr	Andradite	$Ca_3Fe_2Si_3O_{12}$
Alu	Aluminum metal	Al
Ann	Annite	$KFe_3AlSi_3O_{10}(OH)_2$
Ano	Anorthite	$CaAl_2Si_2O_8$
Ant	Anthophyllite	$Mg_7Si_8O_{22}(OH)_2$
Atg	Antigorite	$Mg_{48}Si_{34}O_{85}(OH)_{62}$
Ara	Aragonite	$CaCO_3$
Boe	Boehmite	AlO(OH)
Bru	Brucite	$Mg(OH)_2$
Bun	Bunsenite	NiO
Cts	Ca-Al Clinopyroxene	$CaAl_2SiO_6$
Cc1	Calcite-I	$CaCO_3$
Cc2	Calcite-II	$CaCO_3$
Cal	Calcium	Ca
CO_2	Carbon dioxide	CO_2
Cga	Carnegieite, alpha	$NaAlSiO_4$

Appendix 1. Continued

Code	Phases	Formula
Cgb	Carnegieite, beta	$NaAlSiO_4$
Ctd	Chloritoid	$FeAl_2SiO_5(OH)_2$
Chr	Chrysotile	$Mg_3Si_2O_5(OH)_4$
Cln	Clinochlore	$Mg_5Al_2Si_3O_{10}(OH)_8$
Cen	Clinoenstatite	$MgSiO_3$
Cfs	Clinoferrosilite	$FeSiO_3$
Czo	Clinozoisite	$Ca_2Al_3Si_3O_{12}(OH)$
Crd	Cordierite	$Mg_2Al_4Si_5O_{18}\cdot H_2O$
Col	Calcium olivine	$Ca SiO_4$
Cor	Corundum	Al_2O_3
Cra	Cristobalite, alpha	SiO_2
Crb	Cristobalite, beta	SiO_2
Cwo	Cyclowollastonite	$CaSiO_3$
Dia	Diaspore	$AlO(OH)$
Dic	Dickite	$Al_2Si_2O_5(OH)_4$
H_2O	Dihydrogen oxide	H_2O
Dio	Diopside	$CaMg(SiO_3)_2$
Dol	Dolomite	$CaMg(CO_3)_2$
Ens	Enstatite	$MgSiO_3$
Ept	Epidote	$Ca_2FeAl_2Si_3O_{12}(OH)$
Epi	Epistilbite	$CaAl_2Si_6O_{16}\cdot 5H_2O$
Fay	Fayalite	Fe_2SiO_4

Appendix 1. Continued

Code	Phases	Formula
Fec	Fe-Cordierite	$Fe_2Al_4Si_5O_{18} \cdot H_2O$
Fgh	Ferrigehlenite	$Ca_2Fe_2SiO_7$
Fes	Ferrosilite	$FeSiO_3$
For	Forsterite	Mg_2SiO_4
Geh	Gehlenite	$Ca_2Al_2SiO_7$
Gib	Gibbsite	$Al(OH)_3$
Gra	Graphite	C
Gro	Grossular	$Ca_3Al_2Si_3O_{12}$
Hal	Halloysite	$Al_2Si_2O_5(OH)_4$
Hed	Hedenbergite	$CaFe(SiO_3)_2$
Hem	Hematite	Fe_2O_3
Hcy	Hercynite	$FeAl_2O_4$
Heu	Heulandite	$Ca(Al_2Si_7O_{18}) \cdot 6H_2O$
Hyd	Hydrogen gas	H_2
Ill	Illite	$(K,H_3O)_{x+y}(Mg,Fe)_x$ $Al_{2-x+y}Si_{4-y}O_{10}(OH)_2 \cdot$ $(\_x-y-z)H_2O$ $x+y+z \leqslant 1$
Ilm	Ilmenite	$FeTiO_3$
Irn	Iron	Fe
Jad	Jadeite	$NaAl(SiO_3)_2$
Klp	Kaliophilite	$KAlSiO_4$

Appendix 1. Continued

Code	Phases	Formula
Kal	Kalsilite	$KAlSiO_4$
Kao	Kaolinite	$Al_2Si_2O_5(OH)_4$
Kya	Kyanite	Al_2SiO_5
Lar	Larnite	Ca_2SiO_4
Lau	Laumontite	$CaAl_2Si_4O_{12}\cdot 4H_2O$
Law	Lawsonite	$CaAl_2Si_2O_7(OH)_2\cdot H_2O$
Leo	Leonhardite	$Ca_2Al_4Si_8O_{24}\cdot 7H_2O$
Leu	Leucite	$KAlSi_2O_6$
Lme	Lime	CaO
Mcc	Magnesiocalcite	$(Ca,Mg)CO_3$
Mag	Magnesite	$MgCO_3$
Mgt	Magnetite	Fe_3O_4
Mar	Margarite	$CaAl_4Si_2O_{10}(OH)_2$
Mei	Meionite	$Ca_4Al_6Si_6O_{25}\cdot CO_2$
Mer	Merwinite	$Ca_3Mg(SiO_4)_2$
Mic	Microcline	$KAlSi_3O_8$
Mal	Monalbite	$NaAlSi_3O_8$
Mtc	Monticellite	$CaMgSiO_4$
Mus	Muscovite	$KAl_3Si_3O_{10}(OH)_2$
Nmt	Na-Beidellite	$Na_{.33}Al_2[Al_{.33}Si_{3.67}]O_{10}(OH)_2$
Nat	Natrolite	$Na_2Al_2Si_3O_{10}\cdot 2H_2O$
Nep	Nepheline	$NaAlSiO_4$

Appendix 1. Continued

Code	Phases	Formula
Nic	Nickel	Ni
Ofs	Orthoferrosilite	$FeSiO_3$
Oxy	Oxygen gas	O_2
Par	Paragonite	$NaAl_3Si_3O_{10}(OH)_2$
Per	Periclase	MgO
Phl	Phlogopite	$KMg_3AlSi_3O_{10}(OH)_2$
K2O	Potassium oxide	K_2O
Pre	Prehnite	$Ca_2Al_2Si_3O_{10}(OH)_2$
Pen	Protoenstatite	$MgSiO_3$
Pfs	Protoferrosilite	$FeSiO_3$
Pyt	Pyrite	FeS_2
Pyp	Pyrope	$Mg_3Al_2Si_3O_{12}$
Pyr	Pyrophyllite	$Al_2Si_4O_{10}(OH)_2$
Pyo	Pyrrhotite	$Fe_{1-x}S$
Qza	Quartz, alpha	SiO_2
Qzb	Quartz, beta	SiO_2
Ran	Rankinite	$Ca_3Si_2O_7$
Rut	Rutile	TiO_2
San	Sanidine	$KAlSi_3O_8$
Sid	Siderite	$FeCO_3$
Hsi	"Silicic acid"	H_4SiO_4
Sil	Sillimanite	Al_2SiO_5

Appendix 1. Continued

Code	Phases	Formula
N2O	Sodium oxide	Na_2O
Spl	Spinel	$MgAl_2O_4$
Sta	Staurolite	$Fe_2Al_9Si_4O_{23}(OH)$
H_2O	Steam	H^2O
Stl	Stilbite	$CaAl_2Si_2O_{18} \cdot 7H_2O$
Tlc	Talc	$Mg_3Si_4O_{10}(OH)_2$
Tre	Tremolite	$Ca_2Mg_5Si_8O_{22}(OH)_2$
Wai	Wairakite	$CaAl_2Si_4O_{12} \cdot 2H_2O$
H_2O	Water	H_2O
Wol	Wollastonite	$CaSiO_3$
Wus	Wustite	$Fe_{1-x}O$
Zoi	Zoisite	$Ca_2Al_3Si_3O_{12}(OH)$

Appendix 2. Available experimental data on the thermodynamic properties of selected minerals/phases

The tables of experimental data are arranged alphabetically by mineral name. The tables include mineral name, formula, mineral group, solid solution variability, and a summary of experimental data on the thermodynamic properties of minerals. The summary of experimental data includes literature citation, data type, temperature/pressure range of measurement, and the phases involved in the study. The legend for the phase codes (shown under the "Phases studied" heading in Appendix 2) is given in Appendix 1.

The notation for data type is as follows:

Cp	- heat capacity. Heat capacity typically is measured by low-temperature calorimetry or differential scanning calorimetry.
H_T-H_R	- relative enthalpy. Relative enthalpy typically is measured by drop calorimetry.
S	- entropy. Third-law entropy is calculated by integration of heat capacity from low-temperature calorimetry. Configurational or magnetic contributions to entropy may need to be added to the third-law entropy value.
H	- enthalpy. Data on enthalpy of formation and enthalpy of reaction are included in this category. These properties typically are measured by solution calorimetry or combustion calorimetry. The reaction studied is given under the "Phases studied" heading for each citation.

G - Gibbs energy. Data on Gibbs energy of reaction are included in this category and are measured by phase equilibria studies, electromotive force measurements (emf), or determination of equilibrium constants. The reaction studied is given under the "Phases studied" heading for each citation.

V - molar volume and changes in response to changes in temperature or pressure. The volume properties are typically measured by X-ray diffraction techniques or physical measurements of size or density.

dH/dX - partial molar enthalpy. Partial molar enthalpy is determined by solution calorimetry measurements on a mineral series having variable composition. The composition range of the study is shown in the parentheses given under the "Phases studied" heading for each citation.

a - chemical potential (activity). Chemical potential is determined by phase equilibria studies among phases of variable, but known, composition. The composition range of the study is shown in the parentheses given under the "Phases studied" heading for each citation.

dV/dX - partial molar volume. Partial molar volume typically is measured by X-ray diffraction techniques on a mineral series having variable composition. The composition range of the study is shown in the parentheses given under the "Phases studied" heading for each citation.

Albite - low NaAlSi$_3$O$_8$ - Feldspar group

Al,Si ordered in tetrahedral sites

Important solid solution

(Na,K)	Albite, low - Microcline join (alkali Feldspar series)
(NaSi,CaAl)	Albite, low - Anorthite join (Plagioclase series)
(AlSi order, AlSi disorder in tetrahedral sites)	Albite, low - Analbite join

Reference	Data type	Range (Temperature/pressure)	Phases studied
B.S. Hemingway & others, USGS, unpub. data, 1979	Cp	350-1000 K/1 atm	Alb
Kelley & others, 1953, US Bur. Mines Rpt. Inv. 4955, 21 p	Cp	54-297 K/1 atm	Alb
Openshaw & others, 1976, USGS J. Res., 4, 195-204	Cp	16-373 K/1 atm	Alb
Kelley & others, 1953, US Bur. Mines Rpt. Inv. 4955, 21 p	H_T-H_R	473-1270 K/1 atm	Alb
White, 1919, AJS, 47, 1-59	H_T-H_R	100-1100°C/1 atm	Alb=Ana
Kelley & others, 1953, US Bur. Mines Rpt. Inv. 4955, 21 p	S	298.15 K/1 atm	Alb
Openshaw & others, 1976, USGS J. Res., 4, 195-204	S	298.15 K/1 atm	Alb
Hemingway & Robie, 1977, USGS J. Res., 5, 413-429	H	25°C/1 atm	Alb
Kracek & others, 1951, Wash. Acad. Sci. J., 41, 373-383	H	74.7°C/1 atm	Alb
Newton & others, 1980, Geochim. Cosmo. Acta, 44, 933-941	H	970 K/1 atm	Alb=Ana
Campbell & Fyfe, 1965, AJS, 263, 807-816	G	175-210°C/8.9-19 bars	Anl+Qza=Alb+H_2O
Edgar, 1978, Neues Jahrb. Min., M., 5, 210-222	G	525-555°C/1000 bars	Anl=Alb+Nep+H_2O
Greenwood, 1961, JGR, 66, 3923-3946	G	400-577°C/125-2010 bars	Anl=Alb+Nep+H_2O
Gusynin, 1974, Ocherki Fiz.-Khim. Pet., 4, 23-28	G	510-650°C/1000-4000 bars	Anl=Alb+Nep+H_2O
Hemley & others, 1961, USGS Prof. Paper 424-D, 338-340	G	330°C/1000 bars	Nmt+Alb=Qza+Par
Liou, 1971, Lithos, 4, 389-402	G	178-210°C/2000-5000 bars	Ana+Qza=Alb+H_2O
Liou, 1971, Lithos, 4, 389-402	G	486-604°C/500-3000 bars	Anl=Alb+Nep+H_2O

Manghani, 1970, Phys. Earth Planet. Int., 3, 456-461	G	550-625°C/2500-4500 bars	Anl=Alb+Nep+H_2O
Thompson, 1971, AJS, 271, 79-92	G	150-200°C/2000-5500 bars	Anl+Qza=Alb+H_2O
Hovis & Perkins, 1978, Cont. Min. Pet., 66, 345-349	V	25°C/1 atm	Alb
Kozu & Veda, 1933, Proc. Imp. Acad. Japan, 9, 262-264	V	20-1000°C/1 atm	Alb
Openshaw & others, 1976, USGS J. Res., 4, 195-204	V	25°C/1 atm	Alb
Stewart & von Limbach, 1967, Am. Min., 52, 389-413	V	26-1127°C/1 atm	Alb
Yoder & Weir, 1951, AJS, 249, 683-694	V	24-800°C/1 atm	Alb
Yoder & Weir, 1951, AJS, 249, 683-694	V	24°C/2000-10000 atm	Alb
Orville, 1967, Am. Min., 52, 55-86	dV/dX	25°C/1 atm	Mic+Alb($KAlSi_3O_8$-$NaAlSi_3O_8$ join)

Almandine $Fe_3Al_2Si_3O_{12}$ - Garnet group Alm

Important solid solution

(Fe,Mg)	Almandine - Pyrope join
(Fe,Mn)	Almandine - $Mn_3Al_2Si_3O_{12}$ join

Minor solid solution

(Fe,Ca)	Almandine - Grossular join
$(Fe_3^{+2}Al_2,Ca_3Fe_2^{+3})$	Almandine - Andradite join

Reference	Data type	Range (Temperature/pressure)	Phases studied
Holdaway & Lee, 1977, Cont. Min. Pet., 63, 175-198	G	624-775°C/2700-3800 bars	Fec=Alm+Sil+Qza+H_2O
Liou, 1973, J. Pet., 14, 381-413	G	630-762°C/2000-5000 bars	Ept+Mgt=(Gro+Adr+Alm)+Ano+Qza+Hem+H_2O
Richardson, 1968, J. Pet., 9, 467-488	G		Fec=Alm+Sil+Qza+H_2O
Adams & Gibson, 1929, Proc. Nat. Acad. Sci., 15, 713-724	V	25°C/2000-12000 bars	Alm
Lieberman & Gandall, 1952, J. Am. Ceram. Soc., 35, 304-308	V	293-343 K/1 atm	Alm
Sato & others, 1978, JGR, 83, 335-338	V	25°C/18600-98100 bars	Alm
Skinner, 1956, Am. Min., 41, 428-436	V	25°C/1 atm	Alm
Cressy & others, 1978, Cont. Min. Pet., 67, 397-404	a	850-1100°C/10000-22700 bars	Gro+Alm($Ca_3Al_2Si_3O_{12}$-$Fe_3Al_2Si_3O_{12}$ join)
Cressy & others, 1978, Cont. Min. Pet., 67, 397-404	dV/dX	25°C/1 atm	Gro+Alm($Ca_3Al_2Si_3O_{12}$-$Fe_3Al_2Si_3O_{12}$ join)

Analbite $NaAlSi_3O_8$ - Feldspar group

Al,Si disordered in tetrahedral sites

Important solid solution

(Na,K)	Analbite - Sanidine join (alkali Feldspar series)
(NaSi,CaAl)	Analbite - Anorthite join (Plagioclase series)
(AlSi disorder, AlSi order in tetrahedral sites)	Analbite - Albite, low join (Na-Feldspar series)

Reference	Data type	Range (Temperature/pressure)	Phases studied
B.S. Hemingway & others, USGS, unpub. data, 1979	Cp	350-1000 K/1 atm	Ana
Openshaw & others, 1976, USGS J. Res., 4, 195-204	Cp	16-375 K/1 atm	Ana
White, 1919, AJS, 47, 1-59	H_T-H_R	100-1100°C/1 atm	Alb=Ana
Openshaw & others, 1976, USGS J. Res., 4, 195-204	S	298.15 K/1 atm	Ana
B.S. Hemingway & others, USGS, unpub. data, 1979	H	25°C/1 atm	Ana
Holm & Kleppa, 1968, Am. Min., 53, 123-133	H	700°C/1 atm	Ana
Hovis & Waldbaum, 1977, Am. Min., 62, 680-686	H	49.7°C/1 atm	Ana
Hovis & Waldbaum, 1977, Am. Min., 62, 680-686	H	49.7°C/1 atm	San+Ana($KAlSi_3O_8$-$NaAlSi_3O_8$ join)
Newton & others, 1980, Geochim. Cosmo. Acta, 44, 933-941	H	970 K/1 atm	Alb=Ana
Thompson & others, 1972, The Feldspars, NATO Adv. Study Inst., 218-248	H	25°C/1 atm	Ana
Birch & LeComte, 1960, AJS, 258, 209-217	G	802-1007°C/21280-26040 bars	Ana=Jad+Qza
Chatterjee, 1970, Cont. Min. Pet., 27, 244-257	G	530-670°C/1000-7000 bars	Par=Ana+Cor+H_2O
Chatterjee, 1972, Cont. Min. Pet., 34, 288-303	G	470-600°C/1000-5000 bars	Par+Qza=Ana+And+H_2O
Chatterjee, 1972, Cont. Min. Pet., 34, 288-303	G	570-640°C/5000-7000 bars	Par+Qza=Ana+Kya+H_2O
Essene & others, 1972, EOS, 53, 544	G	800-1200°C/18500-29000 bars	Jad+Kya=Ana+Cor
Essene & others, 1972, EOS, 53, 544	G	800-1200°C/20500-31000 bars	Ana=Jad+Qza
Gusynin & Ivanov, 1971, Dokl. Akad. Nauk SSSR, 197, 1169-1170	G	490-510°C/1000 bars	Par+Qza=Ana+And+H_2O
Gusynin & Ivanov, 1971, Dokl. Akad. Nauk SSSR, 197, 1169-1170	G	530-550°C/1000 bars	Par=Ana+Cor+H_2O

Holland, 1980, Am. Min., 65, 129-134	G	600-1200°C/16000-33000 bars	Ana=Jad+Qza
Johannes & others, 1971, Cont. Min. Pet., 32, 24-38	G	600°C/15700-16800 bars	Ana=Jad+Qza
Liou, 1971, Lithos, 4, 389-402	G	178-210°C/2000-5000 bars	Ana+Qza=Alb+H_2O
Newton & Kennedy, 1968, AJS, 266, 728-735	G	500-600°C/8000-12300 bars	Ana+Nep=Jad
Newton & Smith, 1967, J. Geol., 75, 268-286	G	500-600°C/13500-16900 bars	Ana=Jad+Qza
Hovis, 1977, Am. Min., 62, 672-679	V	25°C/1 atm	Ana
Newton & others, 1980, Geochim. Cosmo. Acta, 44, 933-941	V	25°C/1 atm	Ana
Openshaw & others, 1976, USGS J. Res., 4, 195-204	V	25°C/1 atm	Ana
Stewart & von Limbach, 1967, Am. Min., 52, 389-413	V	26-1026°C/1 atm	Ana
Sueno & others, 1973, EOS, 54, 1230	V	24-1080°C/1 atm	Ana
Winter & others, 1979, Am. Min., 64, 409-423	V	25-1080°C/1 atm	Ana
Newton & others, 1980, Geochim. Cosmo. Acta, 44, 933-941	dH/dX	970 K/1 atm	Ana+Ano($NaAlSi_3O_8$-$CaAl_2Si_2O_8$ join)
Orville, 1972, AJS, 272, 234-272	a	700°C/2000 bars	Ana+Ano($NaAlSi_3O_8$-$CaAl_2Si_2O_8$ join)
Waldbaum & Robie, 1971, Z. Krist., 134, 381-420	dH/dX	49.7°C/1 atm	San+Ana($KAlSi_3O_8$-$NaAlSi_3O_8$ join)
Hovis, 1977, Am. Min., 62, 672-679	dV/dX	25°C/1 atm	San+Ana($KAlSi_3O_8$-$NaAlSi_3O_8$ join)
Newton & others, 1980, Geochim. Cosmo. Acta, 44, 933-941	dV/dX	25°C/1 atm	Ana+Ano($NaAlSi_3O_8$-$CaAl_2Si_2O_8$ join)
Orville, 1967, Am. Min., 52, 55-86	dV/dX	25°C/1 atm	San+Ana($KAlSi_3O_8$-$NaAlSi_3O_8$ join)

Analcite $NaAlSi_2O_6 \cdot H_2O$ - Zeolite group

Anl

Important solid solution

$(H_2O,[])$	$NaAlSi_2O_6 \cdot H_2O$ - $NaAlSi_2O_6 \cdot []$ join
$(NaAl,[]Si)$	$NaAlSi_2O_6 \cdot H_2O$ - $[]Si_3O_6 \cdot H_2O$ join

Reference	Data type	Range (Temperature/pressure)	Phases studied
King & Weller, 1961, US Bur. Mines Rpt. Inv. 5855, 8 p	Cp	53-297 K/1 atm	Anl
King, 1955, J. Am. Chem. Soc., 77, 2192-2193	Cp	53-296 K/1 atm	Anl
Pankratz, 1968, US Bur. Mines Rpt. Inv. 7073, 8 p	H_T-H_R	408-998 K/1 atm	Anl
King & Weller, 1961, US Bur. Mines Rpt. Inv. 5855, 8 p	S	298.15 K/1 atm	Anl
Barany, 1962, US Bur. Mines Rpt. Inv. 5900, 17 p	H	73.7°C/1 atm	Anl
Campbell & Fyfe, 1965, AJS, 263, 807-816	G	175-210°C/8.9-19 bars	$Anl+Qza=Alb+H_2O$
Edgar, 1978, Neues Jahrb. Min., M., 5, 210-222	G	525-555°C/1000 bars	$Anl=Alb+Nep+H_2O$
Greenwood, 1961, JGR, 66, 3923-3946	G	400-577°C/125-2010 bars	$Anl=Alb+Nep+H_2O$
Gusynin, 1974, Ocherki Fiz.-Khim. Pet., 4, 23-28	G	510-650°C/1000-4000 bars	$Anl=Alb+Nep+H_2O$
Liou, 1971, Lithos, 4, 389-402	G	486-604°C/500-3000 bars	$Anl=Alb+Nep+H_2O$
Manghani, 1970, Phys. Earth Planet. Int., 3, 456-461	G	350-600°C/7000-10000 bars	$Anl=Jad+H_2O$
Manghani, 1970, Phys. Earth Planet. Int., 3, 456-461	G	550-625°C/2500-4500 bars	$Anl=Alb+Nep+H_2O$
Thompson, 1971, AJS, 271, 79-92	G	150-200°C/2000-5500 bars	$Anl+Qza=Alb+H_2O$
Edgar, 1978, Neues Jahrb. Min., M., 5, 210-222	V	25°C/1 atm	Anl
Saha, 1959, Am. Min., 44, 300-313	V	25°C/1 atm	Anl
Vaidya & others, 1973, JGR, 78, 6893-6898	V	25°C/5000-45000 bars	Anl
Yoder & Weir, 1960, AJS, 258-A, 420-433	V	25°C/1000-10000 bars	Anl

Andalusite — Al_2SiO_5 - trimorph with Kyanite, Sillimanite

Reference	Data type	Range (Temperature/pressure)	Phases studied
Todd, 1950, J. Am. Chem. Soc., 72, 4742-4743	Cp	206-296 K/1 atm	And
Pankratz & Kelley, 1964, US Bur. Mines Rpt. Inv. 6555, 7 p	H_T-H_R	397-1600 K/1 atm	And
Todd, 1950, J. Am. Chem. Soc., 72, 4742-4743	S	298.15 K/1 atm	And
Anderson & others, 1977, AJS, 277, 585-593	H	973 K/1 atm	Cor+Qza=And
Chatterjee & Johannes, 1974, Cont. Min. Pet., 48, 89-114	G	520-705°C/500-5000 bars	Mus+Qza=San+And+H_2O
Chatterjee, 1972, Cont. Min. Pet., 34, 288-303	G	470-600°C/1000-5000 bars	Par+Qza=Ana+And+H_2O
Gusynin & Ivanov, 1971, Dokl. Akad. Nauk SSSR, 197, 1169-1170	G	490-510°C/1000 bars	Par+Qza=Ana+And+H_2O
Haas & Holdaway, 1973, AJS, 273, 449-464	G	618-722 K/2400-7000 bars	Pyr+Dia=And+H_2O
Haas & Holdaway, 1973, AJS, 273, 449-464	G	643-737 K/2400-7000 bars	And+Qza+H_2O=Pyr
Hemley & others, 1980, Econ. Geol., 75, 210-228	G	623-663 K/1000 bars	Dia+Qza=And+H_2O
Hemley & others, 1980, Econ. Geol., 75, 210-228	G	723-773 K/1000 bars	Cor+Qza=And
Hemley & others, 1980, Econ. Geol., 75, 210-228	G	613-673 K/1000 bars	And+Qza+H_2O=Pyr
Holdaway, 1971, AJS, 271, 97-131	G	650-858 K/2400-4800 bars	Kya=And
Holdaway, 1971, AJS, 271, 97-131	G	764-917 K/1800-3650 bars	And=Sil
Kerrick, 1968, AJS, 266, 204-214	G	668-718 K/1800-3900 bars	And+Qza+H_2O=Pyr
Kerrick, 1972, AJS, 272, 946-958	G	600-610°C/2000 bars	Mus+Qza=San+And+H_2O
Newton, 1966, Sci., 153, 170-172	G	973-1123 K/6100-7400 bars	Kya=And
Storre & Nitsch, 1974, Cont. Min. Pet., 43, 1-24	G	763-833 K/4000-5000 bars	Ano+And+H_2O=Mar+Qzb
Storre & Nitsch, 1974, Cont. Min. Pet., 43, 1-24	G	788-833 K/4000-5000 bars	Ano+And+H_2O=Mar+Qza
Thompson, 1976, Prog. Exp. Pet., Ser. D(6-1976), 12-13	G	390-465°C/500-2000 bars	Ccl+And+Qza=Ano+CO_2
Brace & others, 1969, JGR, 74, 2089-2098	V	25°C/1000-40000 bars	And
Skinner & others, 1961, AJS, 259, 651-668	V	17-1008°C/1 atm	And
Winter & Ghose, 1979, Am. Min., 64, 573-586	V	25-1000°C/1 atm	And

Andradite $Ca_3Fe_2Si_3O_{12}$ - Garnet group

Important solid solution

(Fe^{+3},Al^{+3})	Andradite - Grossular join

Minor solid solution

$(CaFe^{+3},FeAl^{+3})$	Andradite - Almandine join
$(CaFe^{+3},MgAl^{+3})$	Andradite - Pyrope join

Reference	Data type	Range (Temperature/pressure)	Phases studied
Kisleva & others, 1972, Geochem. Int., 9, 1087	H_T-H_R	298-1100 K/1 atm	Adr
Gustafson, 1974, J. Pet., 15, 455-496	G	401-529°C/2000 bars	Hed+Bun=Adr+Mag+Qzb+Nic
Gustafson, 1974, J. Pet., 15, 455-496	G	748-797°C/500-2000 bars	Adr+Fay=Mag+Wol+Qzb
Gustafson, 1974, J. Pet., 15, 455-496	G	789-839°C/500-2000 bars	Adr+Nic=Mag+Wol+Bun
Liou, 1973, J. Pet., 14, 381-413	G	630-762°C/2000-5000 bars	Ept+Mgt=(Gro+Adr+Alm)+Ano+Qza+Hem+H_2O
Liou, 1974, Am. Min., 59, 1016-1025	G	570-610°C/500-2000 bars	Adr+Qza+Fay=Hed+Wol
Liou, 1974, Am. Min., 59, 1016-1025	G	621-683°C/500-2000 bars	Adr+Qza+Nic=Hed+Wol+Bun
Taylor & Liou, 1978, Am. Min., 63, 378-393	G	498-600°C/2000 bars	Qza+Ccl+Hem=Adr+CO_2
Gustafson, 1974, J. Pet., 15, 455-496	V	25°C/1 atm	Adr
Huckenholz & Yoder, 1971, Neues Jahrb. Min., A., 114, 246-280	V	25°C/1 atm	Adr

Annite $KFe_3AlSi_3O_{10}(OH)_2$ - Mica group, Biotite series

Important solid solution

$(Fe^{+2}H, Fe^{+3})$	Annite - $KFe^{+2}Fe_2^{+3}AlSi_3O_{10}(O[])_2$ join
$(Fe^{+2}Si, Al_2)$	Annite - $KFe_2Al_3Si_2O_{10}(OH)_2$ join
(Fe^{+2}, Mg^{+2})	Annite - Phlogopite join

Reference	Data type	Range (Temperature/pressure)	Phases studied
Melchakova & Topor, 1973, Moscow Univ. Geol. Bull., 28, 102-107	H_T-H_R	335-700 K/1 atm	Ann
Day, 1971, PhD Thesis, Brown Univ.	G		Fec+San+H_2O-Ann+Sil+Qza
Eugster & Wones, 1962, J. Pet., 3, 82-125	G	540-550°C/1035 bars	Ann+Qzb+Irn=San+Fay+Wus+H_2O
Eugster & Wones, 1962, J. Pet., 3, 82-125	G	610-640°C/1035-2070 bars	Ann+Bun=San+Mag+Nic+H_2O
Eugster & Wones, 1962, J. Pet., 3, 82-125	G	650-710°C/1035-2070 bars	Ann+Qzb=Mag+San+Fay+H_2O
Eugster & Wones, 1962, J. Pet., 3, 82-125	G	760-765°C/1035 bars	Ann=Leu+Kal+Fay+Irn+Wus+H_2O
Eugster & Wones, 1962, J. Pet., 3, 82-125	G	775-790°C/1035 bars	Ann+Mag=San+Wus+H_2O
Holdaway & Lee, 1977, Cont. Min. Pet., 63, 175-198	G	641-710°C/1900-2800 bars	Fec+San+H_2O=Ann+Sil+Qza
Eugster & Wones, 1962, J. Pet., 3, 82-125	V	25°C/1 atm	Ann

Anorthite $CaAl_2Si_2O_8$ - Feldspar group

Important solid solution

(CaAl,NaSi) Anorthite-Albite, low/Analbite join (Plagioclase series)

Reference	Data type	Range (Temperature/pressure)	Phases studied
Krupka & others, 1979, Am. Min., 64, 86-101	Cp	349-966 K/1 atm	Ano
Robie & others, 1978, Am. Min., 63, 109-123	Cp	202-381 K/1 atm	Ano
White, 1919, AJS, 2d ser., 47(277), 1-59	H_T-H_R	1173-1673 K/1 atm	Ano
Robie & others, 1978, Am. Min., 63, 109-123	S	298.15 K/1 atm	Ano
Charlu & others, 1978, Geochim. Cosmo. Acta, 42, 367-375	H	970 K/1 atm	Ano=Lme+Cor+Qza
Kracek & Neuvonen, 1952, AJS, Bowen Vol., 293-318	H	347.85 K/1 atm	Ano+H_2O=Lme+Gib+Qza
Boettcher, 1970, J. Pet., 11, 337-379	G	1033-1053 K/1000 bars	Ano+Geh=Gro+Cor
Boettcher, 1970, J. Pet., 11, 337-379	G	853-933 K/4000-5300 bars	Gro+Ano+H_2O=Zoi+Qza
Boettcher, 1970, J. Pet., 11, 337-379	G	893-1053 K/3000-5900 bars	Ano+Wol=Gro+Qzb
Boettcher, 1970, J. Pet., 11, 337-379	G	898-928 K/3000 bars	Gro+Ano+Cor+H_2O=Zoi
Chatterjee, 1971, Naturw., 58, 147	G	763-893 K/1000-7000 bars	Ano+Cor+H_2O=Har
Chatterjee, 1974, Schweiz. Min. Petrogr. Mitt., 54, 753-767	G	763-893 K/1000-7000 bars	Ano+Cor+H_2O=Har
Crawford & Fyfe, 1965, AJS, 263, 262-270	G	350-515°C/5170-8900 bars	Law=Ano+H_2O
Goldsmith & Newton, 1977, Am. Min., 62, 1063-1081	G	850-900°C/1000 bars	Ano+Ccl=Mei
Goldsmith & Newton, 1977, Am. Min., 62, 1063-1081	G	850-900°C/5000-15000 bars	Ano+Cc2=Mei
Goldsmith, 1980, Am. Min., 65, 272-284	G	1100-1400°C/22000-31000 bars	Ano=Gro+Kya+Qza
Gordon & Greenwood, 1971, Am. Min., 56, 1674-1688	G	700-849°C/2000 bars	Ccl+Ano+Wol=Gro+CO_2
Hays, 1965, Carn. Inst. Wash. Yb., 234-239	G	1473-1523 K/11000-14600 bars	Gro=Ano+Wol+Geh
Hays, 1965, Carn. Inst. Wash. Yb., 234-239	G	1473-1673 K/11000-14600 bars	Ano+Geh+Cor=Cts
Hewitt, D., 1973, Am. Min., 58, 785-791	G	448-610°C/2000-7000 bars	Mus+Ccl+Qza=San+Ano+CO_2+H_2O
Hoschek, 1974, Cont. Min. Pet., 47, 245-254	G	715-825°C/1000-4000 bars	Ano+Ccl=Gro+Cor+CO_2

Hoschek, 1974, Cont. Min. Pet., 47, 245-254	G	725-825°C/1000 bars	Ano+Ccl=Geh+Gro+CO_2
Hoschek, 1974, Cont. Min. Pet., 47, 245-254	G	725-825°C/1000-4000 bars	Ano+Wol+Ccl=Gro+CO_2
Hoschek, 1974, Cont. Min. Pet., 47, 245-254	G	775-825°C/1000 bars	Ano+Cor+Ccl=Geh+CO_2
Hoschek, 1974, Cont. Min. Pet., 47, 245-254	G	850-890°C/1000 bars	Ano+Ccl=Geh+Wol+CO_2
Huckenholz, 1974, Carn. Inst. Wash. Yb., 411-426	G	1028-1263 K/1000-6000 bars	Ano+Geh=Gro+Cor
Huckenholz, 1974, Carn. Inst. Wash. Yb., 411-426	G	1125-1423 K/200-10000 bars	Gro=Ano+Wol+Geh
Huckenholz, 1974, Carn. Inst. Wash. Yb., 411-426	G	848-858 K/1000-3000 bars	Ano+Wol=Gro+Qza
Huckenholz, 1974, Carn. Inst. Wash. Yb., 411-426	G	888-958 K/4000 bars	Ano+Wol=Gro+Qzb
Juan & Lo, 1971, Proc. Geol. Soc. China, 14, 34-44	G	292-469°C/690-1380 bars	Wai=Ano+Qza+H_2O
Kay & Taylor, 1960, Faraday Soc. Trans., 56, 1372-1386	G	1543 K/1 atm	Ano+Cwo=Geh+Crb
Kay & Taylor, 1960, Faraday Soc. Trans., 56, 1372-1386	G	1653 K/1 atm	Ano=Geh+Cor+Crb
Liou, 1970, Cont. Min. Pet., 27, 259-282	G	325-393°C/500-5000 bars	Wai=Ano+Qza+H_2O
Liou, 1971, Am. Min., 56, 507-531	G	708-828 K/1974-5527 bars	Ano+Wol+H_2O=Pre
Liou, 1973, J. Pet., 14, 381-413	G	630-762°C/2000-5000 bars	Ept+Mgt=(Gro+Adr+Alm)+Ano+Qza+Hem+H_2O
Newton, 1965, J. Geol., 73, 431-441	G	843-1113 K/2000-6800 bars	Gro+Ano+Cor+H_2O=Zoi
Newton, 1966, AJS, 264, 204-222	G	803-923 K/1100-2000 bars	Ano+Wol=Gro+Qza
Newton, 1966, AJS, 264, 204-222	G	973-1023 K/4700-5700 bars	Ano+Wol=Gro+Qzb
Shmulovich, 1974, Geochem. Int., 11, 883-887	G	1133-1153 K/500-700 atm	Gro=Ano+Wol+Geh
Shmulovich, 1977, Geochem. Int., 14, 126-134	G	627-727°C/1000-3920 bars	Ccl+Wol+Ano=Gro+CO_2
Storre & Nitsch, 1972, Cont. Min. Pet., 35, 1-10	G	510-700°C/2000-7000 bars	Zoi+CO_2=Ano+Ccl+H_2O
Storre & Nitsch, 1974, Cont. Min. Pet., 43, 1-24	G	763-833 K/4000-5000 bars	Ano+And+H_2O=Mar+Qzb
Storre & Nitsch, 1974, Cont. Min. Pet., 43, 1-24	G	788-833 K/4000-5000 bars	Ano+And+H_2O=Mar+Qza
Storre & Nitsch, 1974, Cont. Min. Pet., 43, 1-24	G	803-933 K/4000-5000 bars	Ano+Kya+H_2O=Mar+Qza
Strens, 1968, Min. Mag., 36, 864-867	G	770-823 K/2000 bars	Gro+Ano+H_2O=Zoi+Qza
Thompson, 1970, AJS, 269, 267-275	G	300-357°C/1000-6000 bars	Lau=Ano+Qza+H_2O
Thompson, 1976, Prog. Exp. Pet., Ser. D(6-1976), 12-13	G	390-465°C/500-2000 bars	Ccl+And+Qza=Ano+CO_2.
Kozu & Veda, 1933, Proc. Imp. Acad. Japan, 9, 262-264	V	20-1000°C/1 atm	Ano

Rigby & others, 1942, Trans. Brit. Ceram. Soc., 41, 123-143	V	100-1200°C/1 atm	Ano
Robie & others, 1967, USGS Bull. 1248, 87 p	V	25°C/1 atm	Ano
Newton & others, 1980, Geochim. Cosmo. Acta, 44, 933-941	dH/dX	970 K/1 atm	Ana+Ano($NaAlSi_3O_8$-$CaAl_2Si_2O_8$ join)
Orville, 1972, AJS, 272, 234-272	a	700°C/2000 bars	Ana+Ano($NaAlSi_3O_8$-$CaAl_2Si_2O_8$ join)
Newton & others, 1980, Geochim. Cosmo. Acta, 44, 933-941	dV/dX	25°C/1 atm	Ana+Ano($NaAlSi_3O_8$-$CaAl_2Si_2O_8$ join)

Anthophyllite $Mg_7Si_8O_{22}(OH)_2$ - Amphibole group

Reference	Data type	Range (Temperature/pressure)	Phases studied
K.M. Krupka, USGS, unpub. data, 1979	Cp	350-1000 K/1 atm	Ant
Weeks, 1956, J. Geol., 64, 456-472	H	81°C/1 atm	Tre=Ran+Ant+Qza+H_2O
Chernosky & Autio, 1979, Am. Min., 64, 294-303	G	647-742°C/500-3000 bars	Tlc=Ant+Qzb+H_2O
Chernosky & Autio, 1979, Am. Min., 64, 294-303	G	664-775°C/500-2000 bars	Ant=Ens+Qzb+H_2O
Greenwood, 1963, J. Pet., 4, 317-351	G	663-679°C/1000-4000 bars	For+Tlc=Ant+H_2O
Greenwood, 1963, J. Pet., 4, 317-351	G	694-711°C/2000 bars	Tlc=Ant+Qzb+H_2O
Greenwood, 1963, J. Pet., 4, 317-351	G	695-711°C/2000 bars	Ant+For=Ens+H_2O
Greenwood, 1963, J. Pet., 4, 317-351	G	750-775°C/2000-2600 bars	Ant=Ens+Qzb+H_2O
Hemley & others, 1977, AJS, 277, 353-383	G	640-670°C/1000 bars	Ant+Hsl=Tlc+H_2O
Hemley & others, 1977, AJS, 277, 353-383	G	650-670°C/1000 bars	Ant+H_2O=For+Hsl
Hemley & others, 1977, AJS, 277, 353-383	G	660-715°C/1000 bars	Ens+Hsl=Ant+H_2O
Chernosky & Autio, 1979, Am. Min., 64, 294-303	V	25°C/1 atm	Ant
Greenwood, 1963, J. Pet., 4, 317-351	V	25°C/1 atm	Ant

Antigorite $Mg_{48}Si_{34}O_{85}(OH)_{62}$ - Serpentine group

Reference	Data type	Range (Temperature/pressure)	Phases studied
King & others, 1967, US Bur. Mines Rpt. Inv. 6962, 19 p	Cp	53-296 K/1 atm	Atg
King & others, 1967, US Bur. Mines Rpt. Inv. 6962, 19 p	H_T-H_R	405-848 K/1 atm	Atg
King & others, 1967, US Bur. Mines Rpt. Inv. 6962, 19 p	S	298.15 K/1 atm	Atg
Evans & others, 1976, Schweiz. Min. Pet. Mitt., 56, 79-93	G	480-660°C/2000-15000 bars	Atg=For+Tlc+H_2O
Hemley & others, 1977, AJS, 277, 353-383	G	300-450°C/1000 bars	Atg+Hsi=Tlc+H_2O
Hemley & others, 1977, AJS, 277, 353-383	V	25°C/1 atm	Atg
Page & Coleman, 1967, USGS Prof. Paper 575-B, 103-107	V	25°C/1 atm	Atg

Aragonite $CaCO_3$ - dimorph with Calcite

Reference	Data type	Range (Temperature/pressure)	Phases studied
Anderson, 1934, J. Am. Chem. Soc., 56, 340-	C_p		Ara
Staveley & Lingford, 1969, J. Chem. Thermodyn., 1, 1-11	C_p	197-291 K/1 atm	Ara
Kelley, 1960, US Bur. Mines Bull. 584, 232 p	H_T-H_R	350-600 K/1 atm	Ara
Staveley & Lingford, 1969, J. Chem. Thermodyn., 1, 1-11	S	298.15 K/1 atm	Ara
Parker & others, 1971, US NBS Tech. Note 270-6, 106 p	H		Ara
Boettcher & Wyllie, 1968, J. Geol., 76, 314-330	G	400-480°C/8200-9600 bars	Cc1=Ara
Boettcher & Wyllie, 1968, J. Geol., 76, 314-330	G	480-800°C/9000-20100 bars	Cc2=Ara
Goldsmith & Newton, 1969, AJS, 267-A, 160-190	G	400-720°C/9000-22000 bars	Mcc+Dol=Ara+Dol
Goldsmith & Newton, 1969, AJS, 267-A, 160-190	G	400°C/8800-9300 bars	Cc1=Ara
Goldsmith & Newton, 1969, AJS, 267-A, 160-190	G	500-600°C/11200-14400 bars	Cc2=Ara
Johannes & Puhan, 1971, Cont. Min. Pet., 31, 28-38	G	100-480°C/4000-11600 bars	Cc1=Ara
Johannes & Puhan, 1971, Cont. Min. Pet., 31, 28-38	G	450-600°C/11500-15500 bars	Cc2=Ara
Kozu & Kani, 1934, Proc. Imp. Acad. Japan, 10, 222-225	V	25-450°C/1 atm	Ara
Swanson & Fuyat, 1953, US NBS Circ. 539, 2, 65 p	V	25°C/1 atm	Ara

Boehmite AlO(OH) - dimorph with Diaspore

Reference	Data type	Range (Temperature/pressure)	Phases studied
Shomate & Cook, 1946, J. Am. Chem. Soc., 68, 2140-2142	Cp	200-296 K/1 atm	Boe
Shomate & Cook, 1946, J. Am. Chem. Soc., 68, 2140-2142	S	298.15 K/1 atm	Boe
Hemley & others, 1980, Econ. Geol., 75, 210-228	G	473-573 K/1000 bars	Boe+Qza+H_2O=Kao
Robie & others, 1967, USGS Bull. 1248, 87 p	V	25°C/1 atm	Boe

Brucite $Mg(OH)_2$ Bru

Reference	Data type	Range (Temperature/pressure)	Phases studied
Giauque & Archibald, 1937, J. Am. Chem. Soc., 59, 561-569	Cp	20-300 K/1 atm	Bru
King & others, 1975, US Bur. Mines Rpt. Inv. 8041, 13 p	H_T-H_R	350-699 K/1 atm	Bru
Parker & others, 1971, US NBS Tech. Note 270-6, 106 p	S	298 K/1 atm	Bru
Parker & others, 1971, US NBS Tech. Note 270-6, 106 p	H	298 K/1 atm	Bru
Taylor & Wells, 1938, J. Res. NBS, 21, 133-149	H		Bru=Per+H_2O
Barnes & Ernst, 1963, AJS, 261, 129-150	G	544-664°C/240-2000 bars	Bru=Per+H_2O
Fyfe & Goodwin, 1962, AJS, 260, 289-293	G	591-620°C/1034 bars	Bru=Per+H_2O
Fyfe, 1958, AJS, 256, 729-732	G	530-570°C/200-740 bars	Bru=Per+H_2O
Johannes & Metz, 1968, Neues Jahrb. Min., M., 68, 15-26	G	450-600°C/1000 bars	Mag+H_2O=Bru+CO_2
Johannes, 1968, Cont. Min. Pet., 19, 309-315	G	330-440°C/500-7000 bars	Chr+Bru=For+H_2O
Kennedy, 1956, AJS, 254, 567-573	G	500-600°C/130-1175 bars	Bru=Per+H_2O
Walter & others, 1962, J. Pet., 3, 49-64	G	463-666°C/1000-4000 bars	Mag+H_2O=Bru+CO_2
Megaw, 1933, Proc. Roy. Soc. Lond., A142, 198-214	V	293-373 K/1 atm	Bru
Robie & others, 1978, USGS Bull. 1452, 456 p	V	25°C/1 atm	Bru
Swanson & others, 1956, US NBS Circ. 539, 6, 62 p	V	25°C/1 atm	Bru

<u>Calcite - I, II</u> $CaCO_3$ - dimorph with Aragonite

Reference	Data type	Range (Temperature/pressure)	Phases studied
Anderson, 1934, J. Am. Chem. Soc., <u>56</u>, 340-	Cp		Cc1
Jacobs & Kerrick, 1979, EOS, <u>60</u>, 406	Cp	298-775 K/1 atm	Cc1
Staveley & Lingford, 1969, J. Chem. Thermodyn., <u>1</u>, 1-11	Cp	195-303 K/1 atm	Cc1
Kelley, 1960, US Bur. Mines Bull. 584, 232 p	H_T-H_R	400-1200 K/1 atm	Cc1
Staveley & Lingford, 1969, J. Chem. Thermodyn., <u>1</u>, 1-11	S	298.15 K/1 atm	Cc1
Parker & others, 1971, US NBS Tech. Note 270-6, 106 p	H		Cc1
Boettcher & Wyllie, 1968, J. Geol., <u>76</u>, 314-330	G	400-480°C/8200-9600 bars	Cc1=Ara
Boettcher & Wyllie, 1968, J. Geol., <u>76</u>, 314-330	G	480-800°C/9000-20100 bars	Cc2=Ara
Goldsmith & Newton, 1969, AJS, <u>267-A</u>, 160-190	G	400°C/8800-9300 bars	Cc1=Ara
Goldsmith & Newton, 1969, AJS, <u>267-A</u>, 160-190	G	500-600°C/11200-14400 bars	Cc2=Ara
Goldsmith & Newton, 1977, Am. Min., <u>62</u>, 1063-1081	G	850-900°C/1000 bars	Ano+Cc1=Mei
Goldsmith & Newton, 1977, Am. Min., <u>62</u>, 1063-1081	G	850-900°C/5000-15000 bars	Ano+Cc2=Mei
Gordon & Greenwood, 1971, Am. Min., <u>56</u>, 1674-1688	G	700-849°C/2000 bars	Cc1+Ano+Wol=Gro+CO_2
Greenwood, 1967, Am. Min., <u>52</u>, 1669-1680	G	558-595°C/1000-2000 bars	Cc1+Qza-Wol+CO_2
Greenwood, 1967, Am. Min., <u>52</u>, 1669-1680	G	609-723°C/1000-2000 bars	Cc1+Qzb-Wol+CO_2
Harker & Tuttle, 1955, AJS, <u>253</u>, 209-224	G	980-1120°C/100-500 bars	Cc1=Lme+CO_2
Harker & Tuttle, 1956, AJS, <u>254</u>, 239-256	G	600-800°C/300-2400 bars	Cc1+Qzb=Wol+CO_2
Haselton & others, 1978, Geophys. Res. Lett., <u>5</u>, 753-756	G	1000-1325°C/10000-19000 bars	Cc2+Qzb=Wol+CO_2
Hewitt, D., 1973, Am. Min., <u>58</u>, 785-791	G	448-610°C/2000-7000 bars	Mus+Cc1+Qza-San+Ano+CO_2+H_2O
Hewitt, D., 1973, Am. Min., <u>58</u>, 785-791	G	539-540°C/6000 bars	Mus+Cc1+Qza=San+Zoi+CO_2+H_2O
Hewitt, D., 1975, Am. Min., <u>60</u>, 391-397	G	460-681°C/2000-8000 bars	Phl+Cc1+Qza=Tre+San+CO_2+H_2O
Hoschek, 1973, Cont. Min. Pet., <u>39</u>, 231-237	G	495-635°C/4000-6000 bars	Phl+Cc1+Qza=Tre+San+CO_2+H_2O
Hoschek, 1974, Cont. Min. Pet., <u>47</u>, 245-254	G	715-825°C/1000-4000 bars	Ano+Cc1=Gro+Cor+CO_2

Hoschek, 1974, Cont. Min. Pet., 47, 245-254	G	715-825°C/1000-4000 bars	Gro+Cor+Ccl=Geh+CO_2
Hoschek, 1974, Cont. Min. Pet., 47, 245-254	G	725-825°C/1000 bars	Ano+Ccl=Geh+Gro+CO_2
Hoschek, 1974, Cont. Min. Pet., 47, 245-254	G	725-825°C/1000-4000 bars	Ano+Wol+Ccl=Gro+CO_2
Hoschek, 1974, Cont. Min. Pet., 47, 245-254	G	755-788°C/1000 bars	Gro+Ccl=Geh+Wol+CO_2
Hoschek, 1974, Cont. Min. Pet., 47, 245-254	G	775-825°C/1000 bars	Ano+Cor+Ccl=Geh+CO_2
Hoschek, 1974, Cont. Min. Pet., 47, 245-254	G	850-890°C/1000 bars	Ano+Ccl=Geh+Wol+CO_2
Johannes & Puhan, 1971, Cont. Min. Pet., 31, 28-38	G	100-480°C/4000-11600 bars	Ccl=Ara
Johannes & Puhan, 1971, Cont. Min. Pet., 31, 28-38	G	450-600°C/11500-15500 bars	Cc2=Ara
Nitsch, 1972, Cont. Min. Pet., 34, 116-134	G	310-390°C/4000-7000 bars	Ccl+Pyr+H_2O=Law+Qza+CO_2
Shmulovich, 1977, Geochem. Int., 14, 126-134	G	627-727°C/1000-3920 bars	Ccl+Wol+Ano=Gro+CO_2
Storre & Nitsch, 1972, Cont. Min. Pet., 35, 1-10	G	510-700°C/2000-7000 bars	Zoi+CO_2=Ano+Ccl+H_2O
Taylor & Liou, 1978, Am. Min., 63, 378-393	G	498-600°C/2000 bars	Qza+Ccl+Hem=Adr+CO_2
Thompson, 1976, Prog. Exp. Pet., Ser. D(6-1976), 12-13	G	390-465°C/500-2000 bars	Ccl+And+Qza=Ano+CO_2
Adams & others, 1919, J. Am. Chem. Soc., 41, 12-42	V	25°C/1960-12000 bars	Ccl
Bridgeman, 1939, AJS, 237, 7-18	V	25°C/20000-40000 bars	Cc2
Bridgeman, 1939, AJS, 237, 7-18	V	25°C/5000-10000 bars	Ccl
Chessin & others, 1965, Acta Cryst., 18, 689-693	V	25°C/1 atm	Ccl
Graf, 1961, Am. Min., 46, 1283-1316	V	25°C/1 atm	Ccl
Rao & others, 1968, J. Phys. Chem. Solids, 29, 245-248	V	301-797 K/1 atm	Ccl
Rosenholtz & Smith, 1949, Am. Min., 34, 846-854	V	20-700°C/1 atm	Ccl
Vaidya & others, 1973, JGR, 78, 6893-6898	V	25°C/20000-45000 bars	Cc2
Vaidya & others, 1973, JGR, 78, 6893-6898	V	25°C/5000-15000 bars	Ccl

Ca-Al Clinopyroxene CaAl$_2$SiO$_6$ - Pyroxene group

Important solid solution

(Al$_2$,CaSi)	Ca-Al Clinopyroxene - Wollastonite join
(Al$_2$,MgSi)	Ca-Al Clinopyroxene - Diopside join
(Al$_2$,FeSi)	Ca-Al Clinopyroxene - Hedenbergite join

Reference	Data type	Range (Temperature/pressure)	Phases studied
Thompson & others, 1978, EOS, 59, 395	Cp	298.15-1000 K/1 atm	Cts
Charlu & others, 1978, Geochim. Cosmo. Acta, 42, 367-375	H	970 K/1 atm	Cts=Lme+Cor+Qza
Hays, 1965, Carn. Inst. Wash. Yb., 234-239	G	1473-1673 K/11000-14600 bars	Ano+Geh+Cor=Cts
Robie & others, 1967, USGS Bull. 1248, 87 p	V	25°C/1 atm	Cts
Newton & others, 1977, Geochim. Cosmo. Acta, 41, 369-377	dH/dX	970 K/1 atm	Dio+Cts(CaMgSi$_2$O$_6$-CaAl$_2$SiO$_6$ join)
Newton & others, 1977, Geochim. Cosmo. Acta, 41, 369-377	dV/dX	25°C/1 atm	Dio+Cts(CaMgSi$_2$O$_6$-CaAl$_2$SiO$_6$ join)

Carbon Dioxide CO_2 - Gas CO_2

Reference	Data type	Range (Temperature/pressure)	Phases studied
JANAF, 1965	Cp	0-6000 K/1 atm	CO_2
JANAF, 1965	S	0-6000 K/1 atm	CO_2
JANAF, 1965	H	0-6000 K/1 atm	CO_2
C.W. Burnnam & Victor Wall, Pa. St. Univ., unpub. data, 1979	P-V-T	177-977°C/1000-10000 bars	CO_2
Greenwood & Barnes. 1966, GSA Mem., <u>97</u>, 385-400	P-V-T	12-750°C/25-2000 bars	CO_2+H_2O(CO_2-H_2O join)
Greenwood, 1969, AJS, <u>267-A</u>, 191-208	P-V-T	450-800°C/1-500 bars	CO_2+H_2O(CO_2-H_2O join)
Kennedy & Holser, 1966, GSA Mem., <u>97</u>, 371-383	P-V-T	0-1000°C/25-1400 bars	CO_2
Liley, 1956, Rpt. Brit. Admir. DEMR/EN/32/16/1/56	P-V-T		CO_2+H_2O(CO_2-H_2O join)
Powell & others, 1979, Prog. Astronau. Aeronau., <u>66</u>, 325-348	P-V-T	0-900°C/0-10000 bars	CO_2+H_2O(CO_2-H_2O join)
Ryzhenko & Volkov, 1971, Geochem. Int., <u>8</u>, 468-481	P-V-T	100-400°C/1000-4000 bars	CO_2
Takenouchi & Kennedy, 1964, AJS, <u>262</u>, 1055-1074	P-V-T	110-350°C/1-1600 bars	CO_2+H_2O(CO_2-H_2O join)

Chrysotile $Mg_2Si_2O_5(OH)_4$ - Serpentine group

Reference	Data type	Range (Temperature/pressure)	Phases studied
King & others, 1967, US Bur. Mines Rpt. Inv. 6962, 19 p	Cp	53-296 K/1 atm	Chr
King & others, 1967, US Bur. Mines Rpt. Inv. 6962, 19 p	S	298.15 K/1 atm	Chr
King & others, 1967, US Bur. Mines Rpt. Inv. 6962, 19 p	H	25°C/1 atm	Chr
Hemley & others, 1977, AJS, 277, 322-351	G	90-450°C/1 atm-2000 bars	Chr+Hsl-Tlc+H_2O
Johannes, 1968, Cont. Min. Pet., 19, 309-315	G	330-440°C/500-7000 bars	Chr+Bru-For+H_2O
Johannes, 1969, AJS, 267, 1083-1104	G	340-490°C/1000-4000 bars	Chr+CO_2=Tlc+Mag+H_2O
Hemley & others, 1977, AJS, 277, 322-315	V	25°C/1 atm	Chr
Page & Coleman, 1967, USGS Prof. Paper 575-B, 103-107	V	25°C/1 atm	Chr

Clinochlore $Mg_5Al_2Si_3O_{10}(OH)_4$ - Chlorite group

Important solid solution

(Mg,Fe) $Mg_5Al_2Si_3O_{10}(OH)_4$ - $Fe_5Al_2Si_3O_{10}(OH)_4$ join

(MgSi,Al$_2$) $Mg_5Al_2Si_3O_{10}(OH)_4$ - $Mg_4Al_4Si_2O_{10}(OH)_4$ join

Reference	Data type	Range (Temperature/pressure)	Phases studied
Bird & Fawcett, 1973, J. Pet., 14, 415-428	G	634-664°C/8270-9790 bars	Cln+Mus-Phl+Kya+Qza+H_2O
Chernosky, 1974, Am. Min., 59, 496-507	G	576-750°C/500-3000 bars	Cln=For+Spl+Crd+H_2O
Chernosky, 1978, Am. Min., 63, 73-82	G	504-581°C/2000-4000 bars	Cln+Qza-Tlc+Crd+H_2O
Staudigel & Schreyer, 1977, Cont. Min. Pet., 61, 187-198	G	825-890°C/11000-18000 bars	Cln=Ens+For+Spl+H_2O
Staudigel & Schreyer, 1977, Cont. Min. Pet., 61, 187-198	G	870-900°C/22000-35000 bars	Cln=Pyp+For+Spl+H_2O
Widmark, 1980, Cont. Min. Pet., 72, 175-179	G	547-640°C/1000-3000 bars	Cln+Dol=Spl+For+Mcc+CO_2+H_2O
Bird & Fawcett, 1973, J. Pet., 14, 415-428	V	25°C/1 atm	Cln
Chernosky, 1974, Am. Min., 59, 496-507	V	25°C/1 atm	Cln
Staudigel & Schreyer, 1977, Cont. Min. Pet., 61, 187-198	V	25°C/1 atm	Cln

Clinoenstatite $MgSiO_3$ - Pyroxene group; trimorph with Enstatite, Protoenstatite

Important solid solution

(Mg,Ca)	Clinoenstatite - Diopside join
(Mg_2,CaFe)	Clinoenstatite - Hedenbergite join
(Mg_2Si,$CaAl_2$)	Clinoenstatite - Ca-Al Clinopyroxene join
(Mg,Fe)	Clinoenstatite - Clinoferrosilite join

Reference	Data type	Range (Temperature/pressure)	Phases studied
Kelley, 1960, US Bur. Mines Bull. 584, 232 p	H_T-H_R	400-1800 K/1 atm	Cen
Kelley & King, 1961, US Bur. Mines Bull. 592, 149 p	S	298 K/1 atm	Cen
Kelley, 1943, J. Am. Chem. Soc., 65, 339-	S	298.15 K/1 atm	Cen
Torgeson & Sahama, 1948, J. Am. Chem. Soc., 70, 2156-2160	H	25°C/1 atm	Cen
Boyd & England, 1965, Carn. Inst. Wash. Yb., 117-123	G	620-760°C/5000-40000 bars	Ens=Cen
Sarver & Hummel, 1962, J. Am. Chem. Soc., 45, 152-156	G	860-870°C/1 atm	Ens=Cen
Morimoto & others, 1960, Z. Krist., 114, 120-147	V	25°C/1 atm	Cen
Perrotta & Stephenson, 1965, Sci., 148, 1090-1091	V	25°C/1 atm	Cen
Rigby & others, 1942, Trans. Brit. Ceram. Soc., 41, 123-143	V	100-1200°C/1 atm	Cen
Sarver & Hummel, 1962, J. Am. Chem. Soc., 45, 152-156	V	200-700°C/1 atm	Cen
Stephenson & others, 1966, Min. Mag., 35, 838-846	V	26°C/1 atm	Cen

Clinoferrosilite — $FeSiO_3$ - Pyroxene group; trimorph with Ferrosilite, Protoferrosilite — Cfs

Important solid solution

(Fe,Ca)	Clinoferrosilite - Hedenbergite join
(Fe_2,CaMg)	Clinoferrosilite - Diopside join
(Fe_2Si,CaAl_2)	Clinoferrosilite - Ca-Al Clinopyroxene join
(Fe,Mg)	Clinoferrosilite - Clinoenstatite join

Reference	Data type	Range (Temperature/pressure)	Phases studied
Lindsley, 1965, Carn. Inst. Wash. Yb., 148-150	G	775-825°C/10000-40000 bars	Cfs=Fes
Burnham, 1965, Carn. Inst. Wash. Yb., 202-204	V	25°C/1 atm	Cfs

Corundum Al_2O_3 Cor

Reference	Data type	Range (Temperature/pressure)	Phases studied
Chase & others, 1974, J. Phys. Chem. Ref. Data, 3, 311-480	Cp		Cor
Chase & others, 1975, J. Phys. Chem. Ref. Data, 4, 1-176	Cp		Cor
Stull & Prophet, 1971, US NBS NSRDS-NBS 37	Cp		Cor
CODATA Task Group, 1978, CODATA Bull., 28, 1-16	S		Cor
Anderson & Kleppa, 1969, AJS, 267, 285-290	H	974 K/1 atm	Kya=Cor+Qza
Anderson & others, 1977, AJS, 277, 585-593	H	973 K/1 atm	Cor+Qza=And
CODATA Task Group, 1978, CODATA Bull., 28, 1-16	H		Cor
Charlu & others, 1975, Geochim. Cosmo. Acta, 39, 1487-1497	H	970 K/1 atm	Per+Cor=Spl
Charlu & others, 1975, Geochim. Cosmo. Acta, 39, 1487-1497	H	970 K/1 atm	Pyp=Per+Cor+Qzb
Charlu & others, 1978, Geochim. Cosmo. Acta, 42, 367-375	H	970 K/1 atm	Ano=Lme+Cor+Qza
Charlu & others, 1978, Geochim. Cosmo. Acta, 42, 367-375	H	970 K/1 atm	Cts=Lme+Cor+Qza
Charlu & others, 1978, Geochim. Cosmo. Acta, 42, 367-375	H	970 K/1 atm	Gro=Lme+Cor+Qzb
Charlu & others, 1978, Geochim. Cosmo. Acta, 42, 367-375	H	970 K/1 atm	Sil=Cor+Qzb
Shearer & Kleppa, 1973, J. Inorg. Nuc. Chem., 35, 1073-1078	H	965-1173 K/1 atm	Per+Cor=Spl
Taylor & Schmalzried, 1964, J. Phys. Chem., 68, 2444-2449	H	530°C/1 atm	Per+Cor=Spl
Tret'yakov & Schmalzried, 1965, Ber. Bunsenges. Physik. Chem., 69, 396-402	H	1273 K/1 atm	Per+Cor=Spl
Boettcher, 1970, J. Pet., 11, 337-379	G	1033-1053 K/1000 bars	Ano+Geh-Gro+Cor
Boettcher, 1970, J. Pet., 11, 337-379	G	898-928 K/3000 bars	Gro+Ano+Cor+H_2O-Zoi
Chatterjee & Johannes, 1974, Cont. Min. Pet., 48, 89-114	G	600-800°C/1000-8000 bars	Mus=San+Cor+H_2O
Chatterjee, 1970, Cont. Min. Pet., 27, 244-257	G	530-670°C/1000-7000 bars	Par=Ana+Cor+H_2O
Chatterjee, 1971, Naturw., 58, 147	G	763-893 K/1000-7000 bars	Ano+Cor+H_2O=Mar
Chatterjee, 1974, Schweiz. Min. Petrogr. Mitt., 54, 753-767	G	763-893 K/1000-7000 bars	Ano+Cor+H_2O=Mar
Essene & others, 1972, EOS, 53, 544	G	800-1200°C/18500-29000 bars	Jad+Kya=Ana+Cor

Gusynin & Ivanov, 1971, Dokl. Akad. Nauk SSSR, 197, 1169-1170	G	530-550°C/1000 bars	Par=Ana+Cor+H_2O
Haas, 1972, Am. Min., 57, 1375-1385	G	662-741 K/1750-7000 bars	Dia=Cor+H_2O
Hays, 1965, Carn. Inst. Wash. Yb., 234-239	G	1473-1673 K/11000-14600 bars	Ano+Geh+Cor=Cts
Hemley & others, 1980, Econ. Geol., 75, 210-228	G	723-773 K/1000 bars	Cor+Qza=And
Hoschek, 1974, Cont. Min. Pet., 47, 245-254	G	715-825°C/1000-4000 bars	Ano+Ccl=Gro+Cor+CO_2
Hoschek, 1974, Cont. Min. Pet., 47, 245-254	G	715-825°C/1000-4000 bars	Gro+Cor+Ccl=Geh+CO_2
Hoschek, 1974, Cont. Min. Pet., 47, 245-254	G	775-825°C/1000 bars	Ano+Cor+Ccl=Geh+CO_2
Huckenholz, 1974, Carn. Inst. Wash. Yb., 411-426	G	1028-1263 K/1000-6000 bars	Ano+Geh=Gro+Cor
Kay & Taylor, 1960, Faraday Soc. Trans., 56, 1372-1386	G	1653 K/1 atm	Ano=Geh+Cor+Crb
Newton, 1965, J. Geol., 73, 431-441	G	843-1113 K/2000-6800 bars	Gro+Ano+Cor+H_2O=Zoi
Amatuni & Shevchenko, 1966, Izmer. Tekh., 10, 17-20	V	273-773 K/1 atm	Cor
Finger & Hazen, 1978, J. Appl. Phys., 49, 5823-5826	V	23°C/1-80000 bars	Cor
Robie & others, 1967, USGS Bull. 1248, 87 p	V	25°C/1 atm	Cor
Shalnikova & Yakovelv, 1956, Kristall., 1, 531	V		Cor
Strelkov & others, 1966, Meas. Tech., 9, 1116-1120	V	273-1173 K/1 atm	Cor
d'Amour & others, 1978, J. Appl. Phys., 49, 4411-4416	V	25°C/1-90000 bars	Cor

Cristobalite - alpha, beta SiO_2 - polymorph with Quartz, Tridymite, Coesite, Stishovite Cra,Crb

Reference	Data type	Range (Temperature/pressure)	Phases studied
JANAF, 1967	Cp	298-1000 K/1 atm	Cra
JANAF, 1967	Cp	298-3000 K/1 atm	Crb
Westrum, 1963, Phys. Chem. Glass, 4, 188-	Cp	5-300 K/1 atm	Cra
JANAF, 1967	S		Cra
JANAF, 1967	S		Crb
Westrum, 1963, Phys. Chem. Glass, 4, 188-	S	298 K/1 atm	Cra
JANAF, 1967	H		Cra
JANAF, 1967	H		Crb
JANAF, 1967	G		Cra
JANAF, 1967	G		Crb
Kay & Taylor, 1960, Faraday Soc. Trans., 56, 1372-1386	G	1543 K/1 atm	Ano+Cwo=Geh+Crb
Kay & Taylor, 1960, Faraday Soc. Trans., 56, 1372-1386	G	1653 K/1 atm	Ano=Geh+Cor+Crb
Kay & Taylor, 1960, Faraday Soc. Trans., 56, 1372-1386	G	1773 K/1 atm	Lme+Crb=Cwo
Johnson & Andrews, 1956, Trans. Brit. Ceram. Soc., 55, 227-236	V	219-1138°C/1 atm	Crb
Johnson & Andrews, 1956, Trans. Brit. Ceram. Soc., 55, 227-236	V	23-208°C/1 atm	Cra
Robie & others, 1978, USGS Bull. 1452, 456 p	V	25°C/1 atm	Cra

Diaspore   AlO(OH) - dimorph with Boehmite

Reference	Data type	Range (Temperature/pressure)	Phases studied
King & Weller, 1961, US Bur. Mines Rpt. Inv. 5810, 6 p	Cp	206-296 K/1 atm	Dia
Perkins & others, 1979, Am. Min., 64, 1080-1090	Cp	203-345 K/1 atm	Dia
Perkins & others, 1979, Am. Min., 64, 1080-1090	Cp	340-509 K/1 atm	Dia
Perkins & others, 1979, Am. Min., 64, 1080-1090	S	298.15 K/1 atm	Dia
Haas & Holdaway, 1973, AJS, 273, 449-464	G	618-722 K/2400-7000 bars	Pyr+Dia=And+H_2O
Haas, 1972, Am. Min., 57, 1375-1385	G	662-741 K/1750-7000 bars	Dia=Cor+H_2O
Hemley & others, 1980, Econ. Geol., 75, 210-228	G	473-573 K/1000 bars	Dia+Qza+H_2O=Kao
Hemley & others, 1980, Econ. Geol., 75, 210-228	G	523-598 K/1000 bars	Dia+Qza=Pyr
Hemley & others, 1980, Econ. Geol., 75, 210-228	G	623-663 K/1000 bars	Dia+Qza=And+H_2O
Roble & others, 1967, USGS Bull. 1248, 87 p	V	25°C/1 atm	Dia

Dickite $Al_2Si_2O_5(OH)_4$ - Clay group; trimorph with Kaolinite, Halloysite

Reference	Data type	Range (Temperature/pressure)	Phases studied
King & Weller, 1961, US Bur. Mines Rpt. Inv. 5810, 6 p	Cp	206-296 K/1 atm	Dic
King & Weller, 1961, US Bur. Mines Rpt. Inv. 5810, 6 p	S	298.15 K/1 atm	Dic
Barany & Kelley, 1961, US Bur. Mines Rpt. Inv. 5825, 13 p	H	346.85 K/1 atm	Dic+H_2O=Qza+Gib
Robie & others, 1967, USGS Bull. 1248, 87 p	V	25°C/1 atm	Dic

Diopside $CaMgSi_2O_6$ - Pyroxene group

Important solid solution

(Mg,Fe)	Diopside - Hedenbergite join
$(MgSi,Al_2)$	Diopside - Ca-Al Clinopyroxene join
(Ca,Mg)	Diopside - Clinoenstatite join

Reference	Data type	Range (Temperature/pressure)	Phases studied
Kelley, 1960, US Bur. Mines Bull. 584, 232 p	H_T-H_R	400-1600 K/1 atm	Dio
Kelley & King, 1961, US Bur. Mines Bull. 592, 149 p	S	298.15 K/1 atm	Dio
Charlu & others, 1978, Geochim. Cosmo. Acta, 42, 367-375	H	970 K/1 atm	Dio=Lme+Per+Qzb
Kracek & others, 1953, Carn. Inst. Wash. Yb., 69-74	H	74.7°C/1 atm	Dio=Lme+Per+Qza
Navrotsky & Coons, 1976, Geochim. Cosmo. Acta, 40, 1281-1288	H	970 K/1 atm	Dio=Lme+Per+Qzb
Boyd, 1959, Res. Geochem., 1, 377-396	G	800-880°C/575-2000 bars	$Tre=Dio+Ens+Qza+H_2O$
Wones & Dodge, 1977, Thermo. in Geol., 229-247	G	726-774°C/400 bars	$Tre=Dio+Ens+Qza+H_2O$
Wones & Dodge, 1977, Thermo. in Geol., 229-247	G	740-755°C/2000 bars	Tre+San-Phl+Dio+Qza
Adams & Williamson, 1923, J. Franklin Inst., 195, 475-529	V	25°C/2000-12000 bars	Dio
Cameron & others, 1973, Am. Min., 58, 594-618	V	24-1000°C/1 atm	Dio
Clark & others, 1962, Carn. Inst. Wash. Yb., 59-68	V	25°C/1 atm	Dio
Rigby & others, 1942, Trans. Brit. Ceram. Soc., 41, 123-143	V	100-1200°C/1 atm	Dio
Sakata, 1957, Japan. J. Geol. Geog., 28, 161-168	V	25°C/1 atm	Dio
Wones & Dodge, 1977, Thermo. in Geol., 229-247	V	25°C/1 atm	Dio
Newton & others, 1977, Geochim. Cosmo. Acta, 41, 369-377	dH/dX	970 K/1 atm	Dio+Cts($CaMgSi_2O_6$-$CaAl_2SiO_6$ join)
Davis & Boyd, 1966, JGR, 71, 3567-3576	a	900-1675°C/30000 bars	Dio+Ens($MgSiO_3$-$CaMgSi_2O_6$ join)
Mori & Green, 1975, Earth Plant. Sci. Lett., 26, 277-286	a	1100-1700°C/30000 bars	Dio+Ens($MgSiO_3$-$CaMgSi_2O_6$ join)
Nehru & Wyllie, 1974, Cont. Min. Pet., 48, 221-228	a	1000-1500°C/30000 bars	Dio+Ens($MgSiO_3$-$CaMgSi_2O_6$ join)
Warner & Luth, 1974, Am. Min., 59, 98-109	a	900-1300°C/2000-10000 bars	Dio+Ens($MgSiO_3$-$CaMgSi_2O_6$ join)
Newton & others, 1977, Geochim. Cosmo. Acta, 41, 369-377	dV/dX	25°C/1 atm	Dio+Cts($CaMgSi_2O_6$-$CaAl_2SiO_6$ join)

Dolomite $CaMg(CO_3)_2$ Dol

Minor solid solution

(Mg,Ca) Dolomite - Calcite join

Reference	Data type	Range (Temperature/pressure)	Phases studied
Krupka & others, 1977, GSA Abs. Prog., 9, 1060; K.M. Krupka, USGS, unpub. data, 1979	Cp	350-800 K/1 atm	Dol
Stout & Robie, 1963, J. Phys. Chem., 67, 2248-2252	Cp	11-300 K/1 atm	Dol
Stout & Robie, 1963, J. Phys. Chem., 67, 2248-2252	S	278.15 K/1 atm	Dol
R.A. Robie & B.S. Hemingway, USGS, unpub. data, 1979	H	25°C/1 atm	Dol
Goldsmith & Newton, 1969, AJS, 267-A, 160-190	G	400-720°C/9000-22000 bars	Mcc+Dol=Ara+Dol
Gordon & Greenwood, 1970, AJS, 268, 225-242	G	410-522°C/2000 bars	Dol+Qza=Mcc+Tlc+CO_2
Gordon & Greenwood, 1970, AJS, 268, 225-242	G	450-519°C/2000 bars	Dol+Qza=Mcc+Tlc+CO_2
Harker & Tuttle, 1955, AJS, 253, 209-224	G	700-950°C/300-2500 bars	Dol=Per+Mcc+CO_2
Metz & Winkler, 1963, Geochim. Cosmo. Acta, 27, 431-457	G	440-510°C/2000 bars	Dol+Qza=Mcc+Tlc+CO_2
Metz, 1967, Geochim. Cosmo. Acta, 31, 1517-1532	G	450-550°C/500-1000 bars	Tre+Dol=For+Mcc+CO_2+H_2O
Widmark, 1980, Cont. Min. Pet., 72, 175-179	G	547-640°C/1000-3000 bars	Cln+Dol=Spl+For+Mcc+CO_2+H_2O
Graf, 1961, Am. Min., 46, 1283-1316	V	25°C/1 atm	Dol
Goldsmith & Newton, 1969, AJS, 267-A, 160-190	a	400-720°C/1900-21000 bars	Mcc+Dol($CaCO_3$-$MgCO_3$ join)
Graf & Goldsmith, 1958, Geochim. Cosmo. Acta, 13, 218-219	a	575-796°C/10000 PSI	Mcc+Dol($CaCO_3$-$MgCO_3$ join)
Harker & Tuttle, 1955, AJS, 253, 274-282	a	500-9000°C/1379-3103 bars	Mag+Dol($MgCO_3$-$CaCO_3$ join)
Harker & Tuttle, 1955, AJS, 253, 274-282	a	500-900°C/1379-3103 bars	Mcc+Dol($CaCO_3$-$MgCO_3$ join)
Goldsmith & Newton, 1969, AJS, 267-A, 160-190	dV/dX	25°C/1 atm	Mcc+Dol($CaCO_3$-$MgCO_3$ join)

Enstatite $MgSiO_3$ - Pyroxene group; trimorph with Clinoenstatite, Protoenstatite

Important solid solution

(Mg,Fe) Enstatite - Ferrosilite join

($MgSi,Al_2$) Enstatite - $MgAl_2SiO_6$(Mg-Al pyroxene) join

Reference	Data type	Range (Temperature/pressure)	Phases studied
Charlu & others, 1975, Geochim. Cosmo. Acta, 39, 1487-1497	H	970 K/1 atm	Ens=Per+Qzb
Shearer & Kleppa, 1973, J. Inorg. Nuc. Chem., 35, 1073-1078	H	965-1173 K/1 atm	Ens=Per+Qzb
Atlas, 1952, J. Geol., 60, 125-147	G	975-995°C/1 atm	Ens=Pen
Boyd & England, 1965, Carn. Inst. Wash. Yb., 117-123	G	620-760°C/5000-40000 bars	Ens=Cen
Boyd & others, 1964, JGR, 69, 2101-2109	G	1550°C/6100-7400 bars	Ens=Pen
Boyd, 1959, Res. Geochem., 1, 377-396	G	800-880°C/575-2000 bars	Tre=Dio+Ens+Qza+H_2O
Chernosky & Autio, 1979, Am. Min., 64, 294-303	G	664-775°C/500-2000 bars	Ant=Ens+Qzb+H_2O
Chernosky, 1976, Am. Min., 61, 1145-1155	G	600-706°C/500-4000 bars	Tlc+For=Ens+H_2O
Chernosky, 1976, Am. Min., 61, 1145-1155	G	648-744°C/500-2000 bars	Tlc=Ens+Qza+H_2O
Greenwood, 1963, J. Pet., 4, 317-351	G	662-712°C/2000-2600 bars	Tlc+For=Ens+H_2O
Greenwood, 1963, J. Pet., 4, 317-351	G	695-711°C/2000 bars	Ant+For=Ens+H_2O
Greenwood, 1963, J. Pet., 4, 317-351	G	703-775°C/2000-2600 bars	Tlc=Ens+Qzb+H_2O
Greenwood, 1963, J. Pet., 4, 317-351	G	750-775°C/2000-2600 bars	Ant=Ens+Qzb+H_2O
Haselton & others, 1978, Geophys. Res. Lett., 5, 753-756	G	1000-1500°C/20000-40000 bars	Mag+Ens=For+CO_2
Hemley & others, 1977, AJS, 277, 353-383	G	649-690°C/1000 bars	Ens+Hsl=Tlc+H_2O
Hemley & others, 1977, AJS, 277, 353-383	G	660-715°C/1000 bars	Ens+Hsl=Ant+H_2O
Hemley & others, 1977, AJS, 277, 353-383	G	680-720°C/1000 bars	For+Hsl=Ens+H_2O
Hensen & Essene, 1971, Cont. Min. Pet., 30, 72-83	G	1000-1400°C/14400-19800 bars	Ens+Sil=Pyp+Qza
Johannes, 1969, AJS, 267, 1083-1104	G	204-210°C/2000 bars	For+CO_2=Ens+Mag
Newton & Sharp, 1975, Earth Planet. Sci. Lett., 26, 239-244	G	1000-1500°C/19000-20000 bars	Mag+Ens=For+CO_2

Sarver & Hummel, 1962, J. Am. Chem. Soc., 45, 152-156	G	1039-1045°C/1 atm	Ens=Pen
Sarver & Hummel, 1962, J. Am. Chem. Soc., 45, 152-156	G	860-870°C/1 atm	Ens=Cen
Staudigel & Schreyer, 1977, Cont. Min. Pet., 61, 187-198	G	825-890°C/11000-18000 bars	Cln=Ens+For+Spl+H_2O
Staudigel & Schreyer, 1977, Cont. Min. Pet., 61, 187-198	G	900-970°C/20000-21000 bars	Pyp+For=Ens+Spl
Wones & Dodge, 1977, Thermo. in Geol., 229-247	G	726-774°C/400 bars	Tre=Dio+Ens+Qza+H_2O
Wones & Dodge, 1977, Thermo. in Geol., 229-247	G	830-840°C/400-500 bars	Phl+Qzb=San+Ens+H_2O
Wood, 1976, Prog. Exp. Pet., Ser. D(6-1976), 17-19	G	750-790°C/300-470 bars	Phl+Qzb=San+Ens+H_2O
Adams & Williamson, 1923, J. Franklin Inst., 195, 475-529	V	25°C/1960-12000 bars	Ens
Chernosky & Autio, 1979, Am. Min., 64, 294-303	V	25°C/1 atm	Ens
Hess, 1952, AJS, Bowen Vol., 173-187	V	25°C/1 atm	Ens
Ralph & Ghose, 1980, EOS, 61, 409	V	25°C/1-21000 bars	Ens
Sarver & Hummel, 1962, J. Am. Chem. Soc., 45, 152-156	V	200-800°C/1 atm	Ens
Stephenson & others, 1966, Min. Mag., 35, 838-846	V	26°C/1 atm	Ens
Swanson & others, 1956, US NBS Circ. 539, 6, 62 p	V	25°C/1 atm	Ens
Wones & Dodge, 1977, Thermo. in Geol., 229-247	V	25°C/1 atm	Ens
Sahama & Torgeson, 1949, US Bur. Mines Rpt. Inv. 4408	dH/dX	73.7°C/1 atm	Ens+Fes($MgSiO_3$-$FeSiO_3$ join)
Davis & Boyd, 1966, JGR, 71, 3567-3576	a	900-1675°C/30000 bars	Dio+Ens($MgSiO_3$-$CaMgSi_2O_6$ join)
Mori & Green, 1975, Earth Plant. Sci. Lett., 26, 277-286	a	1100-1700°C/30000 bars	Dio+Ens($MgSiO_3$-$CaMgSi_2O_6$ join)
Nehru & Wyllie, 1974, Cont. Min. Pet., 48, 221-228	a	1000-1500°C/30000 bars	Dio+Ens($MgSiO_3$-$CaMgSi_2O_6$ join)
Warner & Luth, 1974, Am. Min., 59, 98-109	a	900-1300°C/2000-10000 bars	Dio+Ens($MgSiO_3$-$CaMgSi_2O_6$ join)

Epidote $Ca_2FeAl_2Si_3O_{12}(OH)$ - Epidote group Ept

Important solid solution

(Fe^{+3},Al) Epidote - Zoisite join

Reference	Data type	Range (Temperature/pressure)	Phases studied
Kiseleva & others, 1974, Geokhim., 4, 543-553	H_T-H_R	335-1100 K/1 atm	Ept
Liou, 1973, J. Pet., 14, 381-413	G	630-762°C/2000-5000 bars	Ept+Mgt-(Grn+Adr+Alm)+Ano+Qtz+Hem+H_2O
Liou, 1973, J. Pet., 14, 381-413	V	25°C/1 atm	Ept

Epistilbite $CaAl_2Si_6O_{16}\cdot5H_2O$ - Zeolite group

Reference	Data type	Range (Temperature/pressure)	Phases studied
Lo, 1978, Proc. Geol. Soc. China, 21, 25-33	G	258-308°C/690-2069 bars	Epi=Wai+Qz+H_2O
Liou, 1970, Cont. Min. Pet., 27, 259-282	V	25°C/1 atm	Epi

Fayalite Fe_2SiO_4 - Olivine group

Important solid solution

(Fe,Mg) Fayalite - Forsterite join

Reference	Data type	Range (Temperature/pressure)	Phases studied
R.A. Robie & others, USGS, unpub. data, 1979	Cp		Fay
Orr, 1953, J. Am. Chem. Soc., 75, 528-529	H_T-H_R	298-1724 K/1 atm	Fay
Kelley & King, 1961, US Bur. Mines Bull. 592, 149 p	S	298.15 K/1 atm	Fay
R.A. Robie & others, USGS, unpub. data, 1979	S	298.15 K/1 atm	Fay
King, 1952, J. Am. Chem. Soc., 74, 4446-4448	H		Fay
Bohlen & others, 1980, Earth Planet. Sci. Lett., 47, 1-10	G	700-850°C/10500-12000 bars	Fes=Fay+Qza
Bohlen & others, 1980, Earth Planet. Sci. Lett., 47, 1-10	G	900-1050°C/12500-15000 bars	Fes=Fay+Qzb
Chou, 1978, Am. Min., 63, 690-703	G	600-800°C/2000-4000 bars	Mgt+Qzb=Fay+Oxy
Eugster & Wones, 1962, J. Pet., 3, 82-125	G	540-550°C/1035 bars	Ann+Qzb+Irn=San+Fay+Wus+H_2O
Eugster & Wones, 1962, J. Pet., 3, 82-125	G	650-710°C/1035-2070 bars	Ann+Qzb=Mag+San+Fay+H_2O
Eugster & Wones, 1962, J. Pet., 3, 82-125	G	760-765°C/1035 bars	Ann=Leu+Kal+Fay+Irn+Wus+H_2O
Gustafson, 1974, J. Pet., 15, 455-496	G	748-797°C/500-2000 bars	Adr+Fay=Hag+Wol+Qzb
Hewitt, 1976, EOS, 57, 1020	G	650-850°C/1000 bars	Mgt+Qzb=Fay+Oxy
Lindsley, 1965, Carn. Inst. Wash. Yb., 148-150	G	1000-1100°C/15500-17000 bars	Fes=Fay+Qza
Lindsley, 1965, Carn. Inst. Wash. Yb., 148-150	G	1275-1280°C/1700-1750 bars	Pfs=Fay+Qza
Liou, 1974, Am. Min., 59, 1016-1025	G	570-610°C/500-2000 bars	Adr+Qza+Fay=Hed+Wol
Smith, 1971, AJS, 271, 370-382	G	1075-1100°C/15500-18000 bars	Fes=Fay+Qzb
Smith, 1971, AJS, 271, 370-382	G	750-900°C/11000-15000 bars	Fes=Fay+Qza
Taylor & Schmalzried, 1964, J. Phys. Chem., 68, 2444-2449	G	900-1100°C/1 atm	Fay
Wones & Gilbert, 1969, AJS, 267-A, 480-488	G	594-803°C/800-2000 bars	Mgt+Qzb=Fay+Oxy
Hazen, 1977, Am. Min., 62, 286-295	V	-196-23°C/1-42000 bars	Fay
Rigby & others, 1946, Trans. Brit. Ceram. Soc., 45, 237-250	V	100-1000°C/1 atm	Fay
Smith, 1975, Am. Min., 60, 1092-1097	V	20-900°C/1 atm	Fay

Ferrosilite $FeSiO_3$ - Pyroxene group

Important solid solution

(Fe,Mg) Ferrosilite - Enstatite join

($FeSi,Al_2$) Ferrosilite - $FeAl_2SiO_6$ (Fe-Al Pyroxene) join

Reference	Data type	Range (Temperature/pressure)	Phases studied
Bohlen & others, 1980, Earth Planet. Sci. Lett., 47, 1-10	G	700-850°C/10500-12000 bars	Fes=Fay+Qza
Bohlen & others, 1980, Earth Planet. Sci. Lett., 47, 1-10	G	900-1050°C/12500-15000 bars	Fes=Fay+Qzb
Lindsley, 1965, Carn. Inst. Wash. Yb., 148-150	G	1000-1100°C/15500-17000 bars	Fes=Fay+Qza
Lindsley, 1965, Carn. Inst. Wash. Yb., 148-150	G	1100-1425°C/20000-45000 bars	Fes=Pfs
Lindsley, 1965, Carn. Inst. Wash. Yb., 148-150	G	775-825°C/10000-40000 bars	Cfs=Fes
Smith, 1971, AJS, 271, 370-382	G	1075-1100°C/15500-18000 bars	Fes=Fay+Qzb
Smith, 1971, AJS, 271, 370-382	G	750-900°C/11000-15000 bars	Fes=Fay+Qza
Burnham, 1965, Carn. Inst. Wash. Yb., 202-204	V	25°C/1 atm	Fes
Sahama & Torgeson, 1949, US Bur. Mines Rpt. Inv. 4408	dH/dX	73.7°C/1 atm	Ens+Fes($MgSiO_3$-$FeSiO_3$ join)
Lindsley & Munoz, 1969, AJS, 267-A, 295-324	a	730-1000°C/20000 bars	Fes+Hed($FeSiO_3$-$CaFeSi_2O_6$ join)

Forsterite Mg_2SiO_4 - Olivine group

Important solid solution

(Mg,Fe) Forsterite - Fayalite join

Reference	Data type	Range (Temperature/pressure)	Phases studied
Orr, 1953, J. Am. Chem. Soc., 75, 528-529	H_T-H_R	298-1808 K/1 atm	For
Kelley & King, 1961, US Bur. Mines Bull. 592, 149 p	S	298.15 K/1 atm	For
Charlu & others, 1975, Geochim. Cosmo. Acta, 39, 1487-1497	H	970 K/1 atm	For
King & others, 1967, US Bur. Mines Rpt. Inv. 6962, 19 p	H	25°C/1 atm	For=Per+Qza
Shearer & Kleppa, 1973, J. Inorg. Nuc. Chem., 35, 1073-1078	H	965-1173 K/1 atm	For+Per+Qzb
Chernosky, 1974, Am. Min., 59, 496-507	G	576-750°C/500-3000 bars	Cln=For+Spl+Crd+H_2O
Chernosky, 1976, Am. Min., 61, 1145-1155	G	600-706°C/500-4000 bars	Tlc+For=Ens+H_2O
Evans & others, 1976, Schweiz. Min. Pet. Mitt., 56, 79-93	G	480-660°C/2000-15000 bars	Atg=For+Tlc+H_2O
Greenwood, 1963, J. Pet., 4, 317-351	G	662-712°C/2000-2600 bars	Tlc+For=Ens+H_2O
Greenwood, 1963, J. Pet., 4, 317-351	G	663-679°C/1000-4000 bars	For+Tlc=Ant+H_2O
Greenwood, 1963, J. Pet., 4, 317-351	G	695-711°C/2000 bars	Ant+For=Ens+H_2O
Haselton & others, 1978, Geophys. Res. Lett., 5, 753-756	G	1000-1500°C/20000-40000 bars	Mag+Ens=For+CO_2
Hemley & others, 1977, AJS, 277, 322-351	G	450-600°C/1000 bars	For+Hsi=Tlc+H_2O
Hemley & others, 1977, AJS, 277, 353-383	G	550-640°C/1000 bars	For+Hsi=Tlc+H_2O
Hemley & others, 1977, AJS, 277, 353-383	G	650-670°C/1000 bars	Ant+H_2O=For+Hsi
Hemley & others, 1977, AJS, 277, 353-383	G	680-720°C/1000 bars	For+Hsi=Ens+H_2O
Johannes, 1968, Cont. Min. Pet., 19, 309-315	G	330-440°C/500-7000 bars	Chr+Bru=For+H_2O
Johannes, 1969, AJS, 267, 1083-1104	G	204-210°C/2000 bars	For+CO_2=Ens+Mag
Johannes, 1969, AJS, 267, 1083-1104	G	450-660°C/500-7000 bars	For+H_2O+CO_2=Tlc+Mag
Metz, 1967, Geochim. Cosmo. Acta, 31, 1517-1532	G	450-550°C/500-1000 bars	Tre+Dol=For+Hcc+CO_2+H_2O
Newton & Sharp, 1975, Earth Planet. Sci. Lett., 26, 239-244	G	1000-1500°C/19000-20000 bars	Mag+Ens=For+CO_2

Staudigel & Schreyer, 1977, Cont. Min. Pet., <u>61</u>, 187-198	G	825-890°C/11000-18000 bars	Cln=Ens+For+Spl+H_2O
Staudigel & Schreyer, 1977, Cont. Min. Pet., <u>61</u>, 187-198	G	870-900°C/22000-35000 bars	Cln=Pyp+For+Spl+H_2O
Staudigel & Schreyer, 1977, Cont. Min. Pet., <u>61</u>, 187-198	G	900-970°C/20000-21000 bars	Pyp+For=Ens+Spl
Widmark, 1980, Cont. Min. Pet., <u>72</u>, 175-179	G	547-640°C/1000-3000 bars	Cln+Dol=Spl+For+Hcc+CO_2+H_2O
Wones, 1967, Geochim. Cosmo. Acta, <u>31</u>, 2248-2253	G	902-1018°C/100-400 bars	Phl=Kal+Leu+For+H_2O
Hazen, 1976, Am. Min., <u>61</u>, 1280-1293	V	-196-1020°C/1-50000 bars	For
Kozu & others, 1934, Proc. Imp. Acad. Japan, <u>10</u>, 83-86	V	20-1000°C/1 atm	For
Olinger & Halleck, 1974, JGR, <u>79</u>, 5535-5536	V	25°C/1-108500 bars	For
Rigby & others, 1942, Trans. Brit. Ceram. Soc., <u>41</u>, 123-143	V	100-1200°C/1 atm	For
Skinner, 1962, USGS Prof. Paper 450-D, 109-112	V	25-1127°C/1 atm	For
Wones, 1967, Geochim. Cosmo. Acta, <u>31</u>, 2248-2253	V	25°C/1 atm	For
Finnerty & Boyd, 1978, Carn. Inst. Wash. Yb., 713-717	a	1000-1400°C/10000-50000 bars	For+Col(Mg_2SiO_4-Ca_2SiO_4 join)
Warner & Luth, 1973, Am. Min., <u>58</u>, 998-1008	a		For+Col(Mg_2SiO_4-Ca_2SiO_4 join)

Gibbsite $Al(OH)_3$ Gib

Reference	Data type	Range (Temperature/pressure)	Phases studied
Hemingway & others, 1977, USGS J. Res., 5, 797-806	Cp	200-480 K/1 atm	Gib
Hemingway & others, 1977, USGS J. Res., 5, 797-806	S	298.15 K/1 atm	Gib
Barany & Kelley, 1961, US Bur. Mines Rpt. Inv. 5810, 6 p	H	346.85 K/1 atm	Hal+H_2O=Qza+Gib
Barany & Kelley, 1961, US Bur. Mines Rpt. Inv. 5810, 6 p	H	346.85 K/1 atm	Kao+H_2O=Qza+Gib
Hemingway & Robie, 1977, USGS J. Res., 5, 413-429	H	303.4 K/1 atm	Alu+H_2O=Gib+Hyd
Kracek & Neuvonen, 1952, AJS, Bowen Vol., 293-318	H	347.85 K/1 atm	Ano+H_2O=Lme+Gib+Qza
Robie & others, 1967, USGS Bull. 1248, 87 p	V	25°C/1 atm	Gib

Graphite C - dimorph with Diamond

Reference	Data type	Range (Temperature/pressure)	Phases studied
JANAF, 1978	Cp	298-6000 K/1 atm	Gra
JANAF, 1978	S	298-6000 K/1 atm	Gra
Nelson & Riley, 1945, Phys. Soc. London Proc., 57, 477-495	V	15-800°C/1 atm	Gra

Grossular $Ca_3Al_2Si_3O_{12}$ - Garnet group

Important solid solution

(Al^{+3}, Fe^{+3})	Grossular - Andradite join

Minor solid solution

(Ca,Fe)	Grossular - Almandine join
(Ca,Mg)	Grossular - Pyrope join

Reference	Data type	Range (Temperature/pressure)	Phases studied
Haselton & Westrum, 1980, Geochim. Cosmo. Acta, <u>44</u>, 701-709	Cp	11-343 K/1 atm	Gro
Kolesnik & others, 1979, Geokhim., 713-721	Cp	14-296 K/1 atm	Gro
Krupka & others, 1979, Am. Min., <u>64</u>, 86-101	Cp	350-978 K/1 atm	Gro
Westrum & others, 1979, J. Chem. Thermodyn., <u>11</u>, 57-66	Cp	200-596 K/1 atm	Gro
Haselton & Westrum, 1980, Geochim. Cosmo. Acta, <u>44</u>, 701-709	S	298.15 K/1 atm	Gro
Westrum & others, 1979, J. Chem. Thermodyn., <u>11</u>, 57-66	S	298.15 K/1 atm	Gro
Charlu & others, 1978, Geochim. Cosmo. Acta, <u>42</u>, 367-375	H	970 K/1 atm	Gro=Lme+Cor+Qzb
Boettcher, 1970, J. Pet., <u>11</u>, 337-379	G	1033-1053 K/1000 bars	Ano+Geh-Gro+Cor
Boettcher, 1970, J. Pet., <u>11</u>, 337-379	G	853-933 K/4000-5300 bars	Gro+Ano+H_2O=Zoi+Qza
Boettcher, 1970, J. Pet., <u>11</u>, 337-379	G	893-1053 K/3000-5900 bars	Ano+Wol-Gro+Qzb
Boettcher, 1970, J. Pet., <u>11</u>, 337-379	G	898-928 K/3000 bars	Gro+Ano+Cor+H_2O-Zoi
Goldsmith, 1980, Am. Min., <u>65</u>, 272-284	G	1100-1400°C/22000-31000 bars	Ano=Gro+Kya+Qza
Gordon & Greenwood, 1971, Am. Min., <u>56</u>, 1674-1688	G	700-849°C/2000 bars	Ccl+Ano+Wol=Gro+CO_2
Hays, 1965, Carn. Inst. Wash. Yb., 234-239	G	1473-1523 K/11000-14600 bars	Gro=Ano+Wol+Geh
Hoschek, 1974, Cont. Min. Pet., <u>47</u>, 245-254	G	715-825°C/1000-4000 bars	Ano+Ccl=Gro+Cor+CO_2
Hoschek, 1974, Cont. Min. Pet., <u>47</u>, 245-254	G	715-825°C/1000-4000 bars	Gro+Cor+Ccl=Geh+CO_2
Hoschek, 1974, Cont. Min. Pet., <u>47</u>, 245-254	G	725-825°C/1000 bars	Ano+Ccl=Geh+Gro+CO_2
Hoschek, 1974, Cont. Min. Pet., <u>47</u>, 245-254	G	725-825°C/1000-4000 bars	Ano+Wol+Ccl-Gro+CO_2

Hoschek, 1974, Cont. Min. Pet., 47, 245-254	G	755-788°C/1000 bars	Gro+Ccl=Geh+Wol+CO_2
Huckenholz, 1974, Carn. Inst. Wash. Yb., 411-426	G	1028-1263 K/1000-6000 bars	Ano+Geh=Gro+Cor
Huckenholz, 1974, Carn. Inst. Wash. Yb., 411-426	G	1125-1423 K/200-10000 bars	Gro=Ano+Wol+Geh
Huckenholz, 1974, Carn. Inst. Wash. Yb., 411-426	G	848-858 K/1000-3000 bars	Ano+Wol=Gro+Qza
Huckenholz, 1974, Carn. Inst. Wash. Yb., 411-426	G	888-958 K/4000 bars	Ano+Wol=Gro+Qzb
Liou, 1973, J. Pet., 14, 381-413	G	630-762°C/2000-5000 bars	Ept+Mgt=(Gro+Adr+Alm)+Ano+Qza+Hem+H_2O
Newton, 1965, J. Geol., 73, 431-441	G	843-1113 K/2000-6800 bars	Gro+Ano+Cor+H_2O=Zoi
Newton, 1966, AJS, 264, 204-222	G	803-923 K/1100-2000 bars	Ano+Wol=Gro+Qza
Newton, 1966, AJS, 264, 204-222	G	973-1023 K/4700-5700 bars	Ano+Wol=Gro+Qzb
Shmulovich, 1974, Geochem. Int., 11, 883-887	G	1133-1153 K/500-700 atm	Gro=Ano+Wol+Geh
Shmulovich, 1977, Geochem. Int., 14, 126-134	G	627-727°C/1000-3920 bars	Ccl+Wol+Ano=Gro+CO_2
Strens, 1968, Min. Mag., 36, 864-867	G	770-823 K/2000 bars	Gro+Ano+H_2O=Zoi+Qza
Adams & Gibson, 1929, Proc. Nat. Acad. Sci., 15, 713-724	V	25°C/2000-12000 bars	Gro
Hazen & Finger, 1978, Am. Min., 63, 297-303	V	25°C/1-61000 bars	Gro
Lieberman & Gandall, 1952, J. Am. Ceram. Soc., 35, 304-308	V	293-343 K/1 atm	Gro
Meagher, 1975, Am. Min., 60, 218-228	V	25-675°C/1 atm	Gro
Robie & others, 1967, USGS Bull. 1248, 87 p	V	25°C/1 atm	Gro
Vaidya & others, 1973, JGR, 78, 6893-6898	V	25°C/5000-45000 bars	Gro
Newton & others, 1977, Geochim. Cosmo. Acta, 41, 369-377	dH/dX	970 K/1 atm	Gro+Pyp($Ca_3Al_2Si_3O_{12}$-$Mg_3Al_2Si_3O_{12}$ join)
Cressy & others, 1978, Cont. Min. Pet., 67, 397-404	a	850-1100°C/10000-22700 bars	Gro+Alm($Ca_3Al_2Si_3O_{12}$-$Fe_3Al_2Si_3O_{12}$ join)
Cressy & others, 1978, Cont. Min. Pet., 67, 397-404	dV/dX	25°C/1 atm	Gro+Alm($Ca_3Al_2Si_3O_{12}$-$Fe_3Al_2Si_3O_{12}$ join)
Newton & others, 1977, Geochim. Cosmo. Acta, 41, 369-377	dV/dX	25°C/1 atm	Gro+Pyp($Ca_3Al_2Si_3O_{12}$-$Mg_3Al_2Si_3O_{12}$ join)

Halloysite $Al_2Si_2O_5(OH)_4$ - Clay group; trimorph with Kaolinite, Dickite

Reference	Data type	Range (Temperature/pressure)	Phases studied
King & Weller, 1961, US Bur. Mines Rpt. Inv. 5810, 6 p	Cp	206-296 K/1 atm	Hal
King & Weller, 1961, US Bur. Mines Rpt. Inv. 5810, 6 p	S	298.15 K/1 atm	Hal
Barany & Kelley, 1961, US Bur. Mines Rpt. Inv. 5810, 6 p	H	346.85 K/1 atm	$Hal+H_2O=Qza+Gib$

Hedenbergite $CaFeSi_2O_6$ - Pyroxene group

Important solid solution

(Fe,Mg)   Hedenbergite - Diopside join
($FeSi,Al_2$)   Hedenbergite - Ca-Al Clinopyroxene join
(Ca,Fe)   Hedenbergite - Clinoferrosilite join

Reference	Data type	Range (Temperature/pressure)	Phases studied
Gustafson, 1974, J. Pet., 15, 455-496	G	401-529°C/2000 bars	Hed+Bun=Adr+Mag+Qzb+Nic
Liou, 1974, Am. Min., 59, 1016-1025	G	570-610°C/500-2000 bars	Adr+Qza+Fay=Hed+Wol
Liou, 1974, Am. Min., 59, 1016-1025	G	621-683°C/500-2000 bars	Adr+Qza+Nic=Hed+Wol+Bun
Cameron & others, 1973, Am. Min., 58, 594-618	V	24-1000°C/1 atm	Hed
Gustafson, 1974, J. Pet., 15, 455-496	V	25°C/1 atm	Hed
Kuno & Hess, 1953, AJS, 251, 741-752	V	25°C/1 atm	Hed
Lindsley, 1967, Carn. Inst. Wash. Yb., 230-234	V	25°C/1 atm	Hed
Rutstein & Yund, 1969, Am. Min., 54, 238-245	V	25°C/1 atm	Hed
Vaidya & others, 1973, JGR, 78, 6893-6898	V	25°C/5000-45000 bars	Hed
Lindsley & Munoz, 1969, AJS, 267-A, 295-324	a	730-1000°C/20000 bars	Fes+Hed($FeSiO_3$-$CaFeSi_2O_6$ join)
Rutstein, 1971, Am. Min., 56, 2040-2052	a	600-1000°C/1000 bars	Wol+Hed($CaSiO_3$-$CaFeSi_2O_6$ join)

Hematite Fe_2O_3

Reference	Data type	Range (Temperature/pressure)	Phases studied
Gronvold & Samuelsen, 1975, J. Phys. Chem., 36, 249-256	Cp	302-1054 K/1 atm	Hem
Gronvold & Westrum, 1959, J. Am. Chem. Soc., 81, 1780-1783	Cp	5.5-345 K/1 atm	Hem
Reznitskii & Filippova, 1972, Neorg. Mater., 8, 481-484	Cp	298-1000 K/1 atm	Hem
Coughlin & others, 1951, J. Am. Chem. Soc., 73, 3891-3893	H_T-H_R	375-1757 K/1 atm	Hem
Gronvold & Westrum, 1959, J. Am. Chem. Soc., 81, 1780-1783	S	298.15 K/1 atm	Hem
Komarov & others, 1967, Neorg. Mater., 3, 1064-1072	G(emf)	1273-1657 K/1 atm	Mag+Oxy-Hem
Liou, 1973, J. Pet., 14, 381-413	G	630-762°C/2000-5000 bars	Ept+Mgt=(Gro+Adr+Alm)+Ano+Qza+Hem+H_2O
Rau, 1972, J. Chem. Thermodyn., 4, 57-64	G	767-840 K/1 atm	Hem+Hyd-Mag+H_2O
Schmahl, 1941, Z. Electrochem., 47, 821-843	G	1583-1683 K/1 atm	Mag+Oxy=Hem
Taylor & Liou, 1978, Am. Min., 63, 378-393	G	498-600°C/2000 bars	Qza+Ccl+Hem=Adr+CO_2
Tret'yakov & Khomyakov, 1962, Russ. J. Inorg. Chem., 7, 628-631	G	1373-1728 K/1 atm	Mag+Oxy-Hem
Gorton & others, 1965, Trans. Metal. Soc. AIME, 233, 1519-1525	V	273-1270 K/1 atm	Hem
Sharma, 1950, Proc. Indian Acad. Sci., A32, 285-291	V	320-670 K/1 atm	Hem

Heulandite $CaAl_2Si_7O_{18}\cdot 6H_2O$ - Zeolite group

Important solid solution

(Ca,Na_2)	Heulandite - $Na_2Al_2Si_7O_{18}\cdot 6H_2O$ join
$(CaSi,NaAl)$	Heulandite - $NaAl_3Si_6O_{18}\cdot 6H_2O$ join
$(H_2O,[])$	Heulandite - $CaAl_2Si_7O_{18}\cdot 6[]$ join

Reference	Data type	Range (Temperature/pressure)	Phases studied
Nitsch, 1968, Naturw., 55, 388	G	160-210°C/7000 bars	Heu=Law+Qz+H_2O
Alberti, 1972, Tsch. Min. Pet. Mitt., 18, 129-146	V	25°C/1 atm	Heu
Miller & Ghent, 1973, Can. Min., 12, 188-192	V	25°C/1 atm	Heu

Illite $(K,H_3O)_{x+y}(Mg,Fe)_xAl_{2-x+y}Si_{4-y}O_{10}(OH)_2\cdot(1-x-y-z)H_2O$* - Clay/Mica group Ill

$x+y+z \leq 1$

Generalized end-member components

$Al_2Si_4O_{10}(OH)_2\cdot H_2O$ - $Al_2Si_4O_{10}(OH)_2$
$KAl_3Si_3O_{10}(OH)_2$ - $(H_3O)Al_3Si_3O_{10}(OH)_2$
$KAl(Mg,Fe)Si_4O_{10}(OH)_2$ - $(H_3O)Al(Mg,Fe)Si_4O_{10}(OH)_2$

* Composition of sample studied for Cp, S: $K_{.75}Mg_{.25}Al_{2.25}Si_{3.5}O_{10}(OH)_2$ X = .25, y = .5, z = .25

Reference	Data type	Range (Temperature/pressure)	Phases studied
Robie & others, 1976, USGS J. Res., 4, 631-644	Cp	15-380 K/1 atm	Ill
Robie & others, 1976, USGS J. Res., 4, 631-644	S	298.15 K/1 atm	Ill

Kaolinite $Al_2Si_2O_5(OH)$ - Clay group; trimorph with Dickite, Halloysite Kao

Reference	Data type	Range (Temperature/pressure)	Phases studied
Hemingway & others, 1978, Geochim. Cosmo. Acta, 42, 1533-1543	Cp	340-800 K/1 atm	Kao
King & Weller, 1961, US Bur. Mines Rpt. Inv. 5810, 6 p	Cp	206-296 K/1 atm	Kao
King & Weller, 1961, US Bur. Mines Rpt. Inv. 5810, 6 p	S	298.15 K/1 atm	Kao
Barany & Kelley, 1961, US Bur. Mines Rpt. Inv. 5810, 6 p	H	346.85 K/1 atm	Kao+H_2O=Qza+Gib
Hemley & others, 1980, Econ. Geol., 75, 210-228	G	473-573 K/1000 bars	Boe+Qza+H_2O=Kao
Hemley & others, 1980, Econ. Geol., 75, 210-228	G	473-573 K/1000 bars	Dia+Qza+H_2O=Kao
Hemley & others, 1980, Econ. Geol., 75, 210-228	G	473-573 K/1000 bars	Kao+Qza=Pyr+H_2O
Robie & others, 1967, USGS Bull. 1248, 87 p	V	25°C/1 atm	Kao

Kyanite Al_2SiO_5 - trimorph with Andalusite, Sillimanite

Reference	Data type	Range (Temperature/pressure)	Phases studied
Todd, 1950, J. Am. Chem. Soc., 72, 4742-4743	Cp	206-296 K/1 atm	Kya
Pankratz & Kelley, 1964, US Bur. Mines Rpt. Inv. 6555, 7 p	H_T-H_R	390-1503 K/1 atm	Kya
Todd, 1950, J. Am. Chem. Soc., 72, 4742-4743	S	298.15 K/1 atm	Kya
Anderson & Kleppa, 1969, AJS, 267, 285-290	H	974 K/1 atm	Kya=Cor+Qza
Bird & Fawcett, 1973, J. Pet., 14, 415-428	G	634-664°C/8270-9790 bars	Cln+Mus=Phl+Kya+Qza+H_2O
Chatterjee, 1972, Cont. Min. Pet., 34, 288-303	G	570-640°C/5000-7000 bars	Par+Qza=Ana+Kya+H_2O
Essene & others, 1972, EOS, 53, 544	G	800-1200°C/18500-29000 bars	Jad+Kya=Ana+Cor
Goldsmith, 1980, Am. Min., 65, 272-284	C	1100-1400°C/22000-31000 bars	Ano=Gro+Kya+Qza
Holdaway, 1971, AJS, 271, 97-131	G	650-858 K/2400-4800 bars	Kya=And
Holland, 1979, Cont. Min. Pet., 68, 293-301	G	550-700°C/23000-26000 bars	Par=Jad+Kya+H_2O
Newton, 1966, Sci., 153, 170-172	G	973-1123 K/6100-7400 bars	Kya=And
Nitsch, 1972, Cont. Min. Pet., 34, 116-134	G	340-385°C/4000-5000 bars	Law=Zoi+Kya+Pyr+H_2O
Storre & Nitsch, 1974, Cont. Min. Pet., 43, 1-24	G	803-933 K/4000-5000 bars	Ano+Kya+H_2O=Mar+Qza
Brace & others, 1969, JGR, 74, 2089-2098	V	25°C/1000-40000 bars	Kya
Skinner & others, 1961, AJS, 259, 651-668	V	25-1055°C/1 atm	Kya
Winter & Ghose, 1979, Am. Min., 64, 573-586	V	25-800°C/1 atm	Kya

Laumontite $CaAl_2Si_4O_{12}\cdot 4H_2O$ - Zeolite group

Important solid solution

(H_2O,[]) Laumontite - $CaAl_2Si_4O_{12}\cdot 4[]$ join

Reference	Data type	Range (Temperature/pressure)	Phases studied
Juan & Lo, 1971, Proc. Geol. Soc. China, <u>14</u>, 34-44	G	250-278°C/890-1380 bars	Lau=Wai+H_2O
Liou, 1971, Cont. Min. Pet., <u>31</u>, 171-177	G	175-200°C/3000-5000 bars	Stl=Lau+Qza+H_2O
Liou, 1971, J. Pet., <u>12</u>, 379-411	G	194-249°C/2800-3500 bars	Lau=Law+Qza+H_2O
Liou, 1971, J. Pet., <u>12</u>, 379-411	G	259-330°C/1000-6000 bars	Lau=Wai+H_2O
Nitsch, 1968, Naturw., <u>55</u>, 388	G	345°C/2500-3500 bars	Lau=Law+Qza+H_2O
Thompson, 1970, AJS, <u>269</u>, 267-275	G	250°C/2500-3000 bars	Lau=Law+Qza+H_2O
Thompson, 1970, AJS, <u>269</u>, 267-275	G	300-357°C/1000-6000 bars	Lau=Ano+Qza+H_2O
Liou, 1971, J. Pet., <u>12</u>, 379-411	V	25°C/1 atm	Lau

Lawsonite $CaAl_2Si_2O_7(OH)_2 \cdot H_2O$

Reference	Data type	Range (Temperature/pressure)	Phases studied
King & Weller, 1961, US Bur. Mines Rpt. Inv. 5855, 8 p	Cp	53-296 K/1 atm	Law
King & Weller, 1961, US Bur. Mines Rpt. Inv. 5855, 8 p	S	298.15 K/1 atm	Law
Barany, 1962, US Bur. Mines Rpt. Inv. 5900, 17 p	h	73.7°C/1 atm	Law
Crawford & Fyfe, 1965, AJS, 263, 262-270	G	350-515°C/5170-8900 bars	Law=Ano+H_2O
Liou, 1971, J. Pet., 12, 379-411	G	194-249°C/2800-3500 bars	Lau=Law+Qza+H_2O
Liou, 1971, J. Pet., 12, 379-411	G	297-381°C/3200-4350 bars	Wai=Law+Qza
Nitsch, 1968, Naturw., 55, 388	G	160-210°C/7000 bars	Heu=Law+Qza+H_2O
Nitsch, 1968, Naturw., 55, 388	G	345°C/2500-3500 bars	Lau=Law+Qza+H_2O
Nitsch, 1972, Cont. Min. Pet., 34, 116-134	G	310-390°C/4000-7000 bars	Ccl+Pyr+H_2O=Law+Qza+CO_2
Nitsch, 1972, Cont. Min. Pet., 34, 116-134	G	340-385°C/4000-5000 bars	Law=Zoi+Kya+Pyr+H_2O
Nitsch, 1972, Cont. Min. Pet., 34, 116-134	G	370-430°C/7000 bars	Law+Qza=Zoi+Pyr+H_2O
Nitsch, 1974, For. Min., 51, 34-35	G	325-445°C/4000-10000 bars	Law=Zoi+Mar+Qza+H_2O
Thompson, 1970, AJS, 269, 267-275	G	250°C/2500-3000 bars	Lau=Law+Qza+H_2O
Baur, 1978, Am. Min., 63, 311-315	V	25°C/1 atm	Law
Pabst, 1961, Z. Krist., 116, 210-219	V		Law
Pistorius, 1961, Am. Min., 46, 982-985	V	25°C/1 atm	Law

Leonhardite $Ca_2Al_4Si_8O_{24}\cdot 7H_2O$ - Zeolite group

Important solid solution

(H_2O,[]) Leonhardite - $Ca_2Al_4Si_8O_{24}\cdot 7[]$ join

Reference	Data type	Range (Temperature/pressure)	Phases studied
King & Weller, 1961, US Bur. Mines Rpt. Inv. 5855, 8 p	Cp	53-296 K/1 atm	Leo
King & Weller, 1961, US Bur. Mines Rpt. Inv. 5855, 8 p	S	298.15 K/1 atm	Leo

Magnesite $MgCO_3$

Important solid solution

(Mg,Ca) Magnesite - Dolomite join

Reference	Data type	Range (Temperature/pressure)	Phases studied
Hemingway & others, 1977, USGS J. Res., 5, 797-806	Cp		Mag
Kelley, 1960, US Bur. Mines Bull. 584, 232 p	H_T-H_R	298-743 K/1 atm	Mag
Hemingway & others, 1977, USGS J. Res., 5, 797-806	S	298.15 K/1 atm	Mag
Harker & Tuttle, 1955, AJS, 253, 209-224	G	600-900°C/165-2757 bars	Mag=Per+CO_2
Harker & Tuttle, 1955, AJS, 253, 209-224	G	600-900°C/165-2758 bars	Mag=Per+CO_2
Haselton & others, 1978, Geophys. Res. Lett., 5, 753-756	G	1000-1500°C/20000-40000 bars	Mag+Ens=For+CO_2
Johannes & Metz, 1968, Neues Jahrb. Min., M., 68, 15-26	G	450-600°C/1000 bars	Mag+H_2O-Bru+CO_2
Johannes & Metz, 1968, Neues Jahrb. Min., M., 68, 15-26	G	635-800°C/500-2000 bars	Mag=Per+CO_2
Johannes & Metz, 1968, Neues Jahrb. Min., M., 68, 15-26	G	700-770°C/500-1000 bars	Mag=Per+CO_2
Johannes, 1969, AJS, 267, 1083-1104	G	204-210°C/2000 bars	For+CO_2=Ens+Mag
Johannes, 1969, AJS, 267, 1083-1104	G	300-600°C/330-7000 bars	Tlc+CO_2=Qza+Mag+H_2O
Johannes, 1969, AJS, 267, 1083-1104	G	340-490°C/1000-4000 bars	Chr+CO_2-Tlc+Mag+H_2O
Johannes, 1969, AJS, 267, 1083-1104	G	450-660°C/500-7000 bars	For+H_2O+CO_2=Tlc+Mag
Newton & Sharp, 1975, Earth Planet. Sci. Lett., 26, 239-244	G	1000-1500°C/19000-20000 bars	Mag+Ens=For+CO_2
Rau, 1972, J. Chem. Thermodyn., 4, 57-64	G	583-810 K/1 atm	Mag+Hyd-Irn+H_2O
Rau, 1972, J. Chem. Thermodyn., 4, 57-64	G	767-840 K/1 atm	Hem+Hyd=Mag+H_2O
Walter & others, 1962, J. Pet., 3, 49-64	G	463-666°C/1000-4000 bars	Mgt+H_2O=Bru+CO_2
Graf, 1961, Am. Min., 46, 1283-1316	V	25°C/1 atm	Mag
Swanson & others, 1957, US NBS Circ. 539, 7, 70 p	V	25°C/1 atm	Mag
Harker & Tuttle, 1955, AJS, 253, 274-282	a	500-9000°C/1379-3103 bars	Mag+Dol($MgCO_3$-$CaCO_3$ join)

Magnesiocalcite $Ca_{1-x}Mg_xCO_3$ - solid solution of Calcite along Calcite - Dolomite join Mcc

Reference	Data type	Range (Temperature/pressure)	Phases studied
Goldsmith & Newton, 1969, AJS, 267-A, 160-190	G	400-720°C/9000-22000 bars	Mcc+Dol=Ara+Dol
Gordon & Greenwood, 1970, AJS, 268, 225-242	G	410-522°C/2000 bars	Dol+Qza=Mcc+Tlc+CO_2
Gordon & Greenwood, 1970, AJS, 268, 225-242	G	450-519°C/2000 bars	Dol+Qza=Mcc+Tlc+CO_2
Harker & Tuttle, 1955, AJS, 253, 209-224	G	700-950°C/300-2500 bars	Dol=Per+Mcc+CO_2
Metz & Winkler, 1963, Geochim. Cosmo. Acta, 27, 431-457	G	440-510°C/2000 bars	Dol+Qza=Mcc+Tlc+CO_2
Metz, 1967, Geochim. Cosmo. Acta, 31, 1517-1532	G	450-550°C/500-1000 bars	Tre+Dol=For+Mcc+CO_2+H_2O
Widmark, 1980, Cont. Min. Pet., 72, 175-179	G	547-640°C/1000-3000 bars	Cln+Dol=Spl+For+Mcc+CO_2+H_2O
Goldsmith & Newton, 1969, AJS, 267-A, 160-190	a	400-720°C/1900-21000 bars	Mcc+Dol($CaCO_3$-$MgCO_3$ join)
Graf & Goldsmith, 1958, Geochim. Cosmo. Acta, 13, 218-219	a	575-796°C/10000 PSI	Mcc+Dol($CaCO_3$-$MgCO_3$ join)
Harker & Tuttle, 1955, AJS, 253, 274-282	a	500-900°C/1379-3103 bars	Mcc+Dol($CaCO_3$-$MgCO_3$ join)
Goldsmith & Newton, 1969, AJS, 267-A, 160-190	dV/dX	25°C/1 atm	Mcc+Dol($CaCO_3$-$MgCO_3$ join)

Magnetite Fe_3O_4 Mgt

Reference	Data type	Range (Temperature/pressure)	Phases studied
Gronvold & Sveen, 1974, J. Chem. Thermodyn., <u>6</u>, 859-872	Cp	300-1044 K/1 atm	Mgt
Westrum & Gronvold, 1969, J. Chem. Thermodyn., <u>1</u>, 543-557	Cp	6.49-348 K/1 atm	Mgt
Coughlin & others, 1951, J. Am. Chem. Soc., <u>73</u>, 3891-3893	H_T-H_R	351-1825 K/1 atm	Mgt
Westrum & Gronvold, 1969, J. Chem. Thermodyn., <u>1</u>, 543-557	S	298.15 K/1 atm	Mgt
Birks, 1966, Nature, <u>210</u>, 407-408	G(emf)	838 K/1 atm	Wus=Irn+Mgt
Chou, 1978, Am. Min., <u>63</u>, 690-703	G	600-800°C/2000-4000 bars	Mgt+Qzb=Fay+Oxy
Darken & Gurry, 1945, J. Am. Chem. Soc., <u>67</u>, 1398-1412	G	1369-1661 K/1 atm	Wus+CO_2=Mgt+CO
Emmett & Schultz, 1933, J. Am. Chem. Soc., <u>55</u>, 1376-1389	G	673-823 K/1 atm	Mgt+Hyd=Irn+H_2O
Emmett & Schultz, 1933, J. Am. Chem. Soc., <u>55</u>, 1376-1389	G	873-1073 K/1 atm	Mgt+H_2O=Wus+H_2O
Eugster & Wones, 1962, J. Pet., <u>3</u>, 82-125	G	610-640°C/1035-2070 bars	Ann+Bun=San+Mgt +Nic+H_2O
Eugster & Wones, 1962, J. Pet., <u>3</u>, 82-125	G	650-710°C/1035-2070 bars	Ann+Qzb=Mgt+San+Fay+H_2O
Eugster & Wones, 1962, J. Pet., <u>3</u>, 82-125	G	775-790°C/1035 bars	Ann+Mgt-San+Wus+H_2O
Gustafson, 1974, J. Pet., <u>15</u>, 455-496	G	401-529°C/2000 bars	Hed+Bun=Adr+Mgt+Qzb+Nic
Gustafson, 1974, J. Pet., <u>15</u>, 455-496	G	748-797°C/500-2000 bars	Adr+Fay-Mgt+Wol+Qzb
Gustafson, 1974, J. Pet., <u>15</u>, 455-496	G	789-839°C/500-2000 bars	Adr+Nil-Mgt+Wol +Nic
Hewitt, 1976, EOS, <u>57</u>, 1020	G	650-850°C/1000 bars	Mgt+Qzb-Fay+Oxy
Komarov & others, 1967, Neorg. Mater., <u>3</u>, 1064-1072	G(emf)	1273-1657 K/1 atm	Mgt+Oxy-Hem
Liou, 1973, J. Pet., <u>14</u>, 381-413	G	630-762°C/2000-5000 bars	Ept+Mgt=(Grn+Adr+Alm)+Ann+Qza+Hem+H_2O
Rau, 1972, J. Chem. Thermodyn., <u>4</u>, 57-64	G	859-882 K/1 atm	Mgt+H_2O=Wus+H_2O
Schmahl, 1941, Z. Electrochem., <u>47</u>, 821-843	G	1583-1683 K/1 atm	Mgt+Oxy-Hem
Tret'yakov & Khomyakov, 1962, Russ. J. Inorg. Chem., <u>7</u>, 628-631	G	1373-1728 K/1 atm	Mgt+Oxy-Hem
Vallet & Raccah, 1965, Mem. Sci. Rev. Metal., <u>62</u>, 1-29	G	1133-1398 K/1 atm	Wus+CO_2-Mgt+CO
Wones & Gilbert, 1969, AJS, <u>267-A</u>, 480-488	G	594-803°C/800-2000 bars	Mgt+Qzb-Fay+Oxy
Sharma, 1950, Proc. Indian Acad. Sci., <u>A31</u>, 261-274	V	314-843 K/1 atm	Mgt
Darken & Gurry, 1946, J. Am. Chem. Soc., <u>68</u>, 798-816	a	1401-1866 K/1 atm	Mgt(FeO-Fe_2O_3 join)

Margarite $CaAl_4Si_2O_{10}(OH)_2$ - Mica group

Important solid solution

(CaAl,NaSi) Margarite - Paragonite join

Reference	Data type	Range (Temperature/pressure)	Phases studied
Perkins & others, 1980, Geochim. Cosmo. Acta, 44, 61-84	Cp	298-1000 K/1 atm	Mar
Perkins & others, 1980, Geochim. Cosmo. Acta, 44, 61-84	S	298.15 K/1 atm	Mar
Chatterjee, 1971, Naturw., 58, 147	G	763-893 K/1000-7000 bars	Ano+Cor+H_2O=Mar
Chatterjee, 1974, Schweiz. Min. Petrogr. Mitt., 54, 753-767	G	763-893 K/1000-7000 bars	Ano+Cor+H_2O=Mar
Nitsch, 1974, For. Min., 51, 34-35	G	325-445°C/4000-10000 bars	Law=Zoi+Mar+Qza+H_2O
Storre & Nitsch, 1974, Cont. Min. Pet., 43, 1-24	G	763-833 K/4000-5000 bars	Ano+And+H_2O=Mar+Qzb
Storre & Nitsch, 1974, Cont. Min. Pet., 43, 1-24	G	788-833 K/4000-5000 bars	Ano+And+H_2O=Mar+Qza
Storre & Nitsch, 1974, Cont. Min. Pet., 43, 1-24	G	803-933 K/4000-5000 bars	Ano+Kya+H_2O=Mar+Qza
Robie & others, 1967, USGS Bull. 1248, 87 p	V	25°C/1 atm	Mar
Franz & others, 1977, Cont. Min. Pet., 59, 307-316	a	400-600°C/1000-6000 bars	Par+Mar($NaAl_3Si_3O_{10}(OH)_2$-$CaAl_4Si_2O_{10}(OH)_2$ join)
Franz & others, 1977, Cont. Min. Pet., 59, 307-316	dV/dX	25°C/1 atm	Par+Mar($NaAl_3Si_3O_{10}(OH)_2$-$CaAl_4Si_2O_{10}(OH)_2$ join)

Microcline $KAlSi_3O_8$ - Feldspar group

Al,Si ordered in tetrahedral sites

Important solid solution

(K,Na) Microcline - Albite, low join (alkali Feldspar series)

(AlSi order, AlSi disorder in tetrahedral sites) Microcline - Sanidine (K-Feldspar series)

Reference	Data type	Range (Temperature/pressure)	Phases studied
B.S. Hemingway & others, USGS, unpub. data, 1979	Cp	350-1000°C/1 atm	Mic
Openshaw & others, 1976, USGS J. Res., 4, 195-204	Cp	16-373 K/1 atm	Mic
Kelley, 1960, US Bur. Mines Bull. 584, 232 p	H_T-H_R	400-1400 K/1 atm	Mic
Openshaw & others, 1976, USGS J. Res., 4, 195-204	S	298.15 K/1 atm	Mic
Waldbaum & Robie, 1971, Z. Krist., 184, 381-421	H	25°C/1 atm	Mic
Adams & Williamson, 1923, J. Franklin Inst., 195, 475-529	V	25°C/2000-12000 bars	Mic
Finney & Bailey, 1964, Z. Krist., 119, 413-436	V	25°C/1 atm	Mic
Hovis & Perkins, 1978, Cont. Min. Pet., 66, 345-349	V	25°C/1 atm	Mic
Openshaw & others, 1953, USGS J. Res., 4, 195-204	V	25°C/1 atm	Mic
Orville, 1967, Am. Min., 52, 55-86	dV/dX	25°C/1 atm	Mic+Alb($KAlSi_3O_8$-$NaAlSi_3O_8$ join)

Montmorillonite $(1/2Ca,Na)_{(x+y+z)}(Al_{2-x-2z},(Mg,Fe)_x,Fe_{+2}^{+3})(Al_{y+z},Si_{4-y-z})O_{10}(OH)_2 \cdot nH_2O$ - Nmt

Smectite Clay group, $x+y+z \leq 0.33$, $n \leq 2$

Generalized end-member components

Alkali-free Montmorillonite - $Al_2Si_4O_{10}(OH)_2 \cdot nH_2O$

Montmorillonite - $(1/2Ca,Na)_{0.33}(Al_{1.67},(Mg,Fe)_{0.33})Si_4O_{10}(OH)_2 \cdot nH_2O$

Beidellite - $(1/2Ca,Na)_{0.33}(Al_2)(Al_{0.33},Si_{3.67})O_{10}(OH)_2 \cdot nH_2O$

Nontronite - $(1/2Ca,Na)_{0.33}(Fe_2^{+3})(Al_{0.33},Si_{3.67})O_{10}(OH)_2 \cdot nH_2O$ - $n \leq 2$

* Composition of sample studied by phase equilibria experiments (G):

Na-Beidellite - $Na_{.33}Al_{2.33}Si_{3.67}O_{10}(OH)_2$, $x = 0$, $y = 0.33$, $z = 0$, $n = 0$

Reference	Data type	Range (Temperature/pressure)	Phases studied
Hemley & others, 1961, USGS Prof. Paper 424-D, 338-340	G	330°C/1000 bars	Nmt+Alb=Qza+Par

Muscovite $KAl_3Si_3O_{10}(OH)_2$ - Mica group

Important solid solution

(K,Na) Muscovite - Paragonite join

Reference	Data type	Range (Temperature/pressure)	Phases studied
Krupka & others, 1979, Am. Min., 64, 86-101	Cp	333-967 K/1 atm	Mus
Robie & others, 1976, USGS J. Res., 4, 631-644	Cp	13-385 K/1 atm	Mus
Weller & King, 1963, US Bur. Mines Rpt. Inv. 6281, 4 p	Cp	53-297 K/1 atm	Mus
Melchakova & Topor, 1973, Moscow Univ. Geol. Bull., 28, 102-107	H_T-H_R	335-900 K/1 atm	Mus
Pankratz, 1964, US Bur. Mines Rpt. Inv. 6371, 6 p	H_T-H_R	394-903 K/1 atm	Mus
Robie & others, 1976, USGS J. Res., 4, 631-644	S	298.15 K/1 atm	Mus
Weller & King, 1963, US Bur. Mines Rpt. Inv. 6281, 4 p	S	298.15 K/1 atm	Mus
Barany, 1964, US Bur. Mines Rpt. Inv. 6356, 6 p	H	73.7°C/1 atm	Mus
Sommerfeld, 1967, J. Geol., 75, 477-487	H	80°C/1 atm	Mus
Bird & Fawcett, 1973, J. Pet., 14, 415-428	G	634-664°C/8270-9790 bars	$Cln+Mus=Phl+Kya+Qza+H_2O$
Chatterjee & Johannes, 1974, Cont. Min. Pet., 48, 89-114	G	520-705°C/500-5000 bars	$Mus+Qza=San+And+H_2O$
Chatterjee & Johannes, 1974, Cont. Min. Pet., 48, 89-114	G	540-720°C/500-6000 bars	$Mus+Qza=San+Sil+H_2O$
Chatterjee & Johannes, 1974, Cont. Min. Pet., 48, 89-114	G	600-800°C/1000-8000 bars	$Mus=San+Cor+H_2O$
Day, 1973, Am. Min., 58, 255-262	G	580-668°C/1000-3000 bars	$Mus+Qza=San+Sil+H_2O$
Hewitt, D., 1973, Am. Min., 58, 785-791	G	448-610°C/2000-7000 bars	$Mus+Ccl+Qza=San+Ano+CO_2+H_2O$
Hewitt, D., 1973, Am. Min., 58, 785-791	G	539-540°C/6000 bars	$Mus+Ccl+Qza=San+Zoi+CO_2+H_2O$
Kerrick, 1972, AJS, 272, 946-958	G	600-610°C/2000 bars	$Mus+Qza=San+And+H_2O$
Yoder & Eugster, 1955, Geochim. Cosmo. Acta, 8, 255-277	V	25°C/1 atm	Mus
Blencoe, 1973, GSA Abs. Prog., 553-554	a	400-580°C/2000-8000 bars	$Mus+Par(KAl_3Si_3O_{10}(OH)_2-NaAl_3Si_3O_{10}(OH)_2$ join)
Eugster & others, 1972, J. Pet., 13, 147-179	a	300-600°C/2070 bars	$Mus+Par(KAl_3Si_3O_{10}(OH)_2-NaAl_3Si_3O_{10}(OH)_2$ join)
Eugster & others, 1972, J. Pet., 13, 147-179	dV/dX	25°C/1 atm	$Mus+Par(KAl_3Si_3O_{10}(OH)_2-NaAl_3Si_3O_{10}(OH)_2$ join)

Paragonite $NaAl_3Si_3O_{10}(OH)_2$ - Mica group

Important solid solution

(Na,K) Paragonite - Muscovite join

Reference	Data type	Range (Temperature/pressure)	Phases studied
B.S. Hemingway & others, USGS, unpub. data, 1979	Cp	200-800 K/1 atm	Par
B.S. Hemingway & others, USGS, unpub. data, 1979	Cp	6-307 K/1 atm	Par
B.S. Hemingway & others, USGS, unpub. data, 1979	S	298.15 K/1 atm	Par
Chatterjee, 1970, Cont. Min. Pet., <u>27</u>, 244-257	G	530-670°C/1000-7000 bars	Par=Ana+Cor+H_2O
Chatterjee, 1972, Cont. Min. Pet., <u>34</u>, 288-303	G	470-600°C/1000-5000 bars	Par+Qza=Ana+And+H_2O
Chatterjee, 1972, Cont. Min. Pet., <u>34</u>, 288-303	G	570-640°C/5000-7000 bars	Par+Qza=Ana+Kya+H_2O
Gusynin & Ivanov, 1971, Dokl. Akad. Nauk SSSR, <u>197</u>, 1169-1170	G	490-510°C/1000 bars	Par+Qza-Ana+And+H_2O
Gusynin & Ivanov, 1971, Dokl. Akad. Nauk SSSR, <u>197</u>, 1169-1170	G	530-550°C/1000 bars	Par=Ana+Cor+H_2O
Hemley & others, 1961, USGS Prof. Paper 424-D, 338-340	G	330°C/1000 bars	Nmt+Alb-Qza+Par
Holland, 1979, Cont. Min. Pet., <u>68</u>, 293-301	G	550-700°C/23000-26000 bars	Par=Jad+Kya+H_2O
Chatterjee, 1974, Cont. Min. Pet., <u>43</u>, 25-28	V	25°C/1 atm	Par
Holland, 1979, Cont. Min. Pet., <u>68</u>, 293-301	V	25°C/1 atm	Par
Blencoe, 1973, GSA Abs. Prog., 553-554	a	400-580°C/2000-8000 bars	Mus+Par($KAl_3Si_3O_{10}(OH)_2$-$NaAl_3Si_3O_{10}(OH)_2$ join)
Eugster & others, 1972, J. Pet., <u>13</u>, 147-179	a	300-600°C/2070 bars	Mus+Par($KAl_3Si_3O_{10}(OH)_2$-$NaAl_3Si_3O_{10}(OH)_2$ join)
Franz & others, 1977, Cont. Min. Pet., <u>59</u>, 307-316	a	400-600°C/1000-6000 bars	Par+Mar($NaAl_3Si_3O_{10}(OH)_2$-$CaAl_4Si_2O_{10}(OH)_2$ join)
Eugster & others, 1972, J. Pet., <u>13</u>, 147-179	dV/dX	25°C/1 atm	Mus+Par($KAl_3Si_3O_{10}(OH)_2$-$NaAl_3Si_3O_{10}(OH)_2$ join)
Franz & others, 1977, Cont. Min. Pet., <u>59</u>, 307-316	dV/dX	25°C/1 atm	Par+Mar($NaAl_3Si_3O_{10}(OH)_2$-$CaAl_4Si_2O_{10}(OH)_2$ join)

Phlogopite

$KMg_3AlSi_3O_{10}(OH)_2$ - Mica group, Biotite series

Important solid solution

(Mg,Fe) Phlogopite - Annite

(MgSi,Al_2) Phlogopite - $KMg_2Al_3Si_2O_{10}(OH)_2$ join

Reference	Data type	Range (Temperature/pressure)	Phases studied
Melchakova & Topor, 1973, Moscow Univ. Geol. Bull., <u>28</u>, 102-107	H_T-H_R	335-1100 K/1 atm	Phl
Bird & Fawcett, 1973, J. Pet., <u>14</u>, 415-428	G	634-664°C/8270-9790 bars	Cln+Mus-Phl+Kya+Qza+H_2O
Hewitt, D., 1975, Am. Min., <u>60</u>, 391-397	G	460-681°C/2000-8000 bars	Phl+Ccl+Qza=Tre+San+CO_2+H_2O
Hoschek, 1973, Cont. Min. Pet., <u>39</u>, 231-237	G	495-635°C/4000-6000 bars	Phl+Ccl+Qza=Tre+San+CO_2+H_2O
Wones & Dodge, 1977, Thermo. in Geol., 229-247	G	740-755°C/2000 bars	Tre+San-Phl+Dio+Qza
Wones & Dodge, 1977, Thermo. in Geol., 229-247	G	830-840°C/400-500 bars	Phl+Qzb=San+Ens+H_2O
Wones, 1967, Geochim. Cosmo. Acta, <u>31</u>, 2248-2253	G	902-1018°C/100-400 bars	Phl=Kal+Leu+For+H_2O
Wood, 1976, Prog. Exp. Pet., Ser. D(6-1976), 17-19	G	750-790°C/300-470 bars	Phl+Qzb=San+Ens+H_2O
Adams & Williamson, 1923, J. Franklin Inst., <u>195</u>, 475-529	V	25°C/1960-7840 bars	Phl
Hazen & Finger, 1978, Am. Min., <u>63</u>, 293-296	V	25°C/1-47000 bars	Phl
Hewitt, 1975, Am. Min., <u>60</u>, 391-397	V	25°C/1 atm	Phl
Takeda & Morosin, 1975, Acta Cryst., <u>B31</u>, 2444-2452	V	24-900°C/1 atm	Phl
Wones & Dodge, 1977, Thermo. in Geol., 229-247	V	25°C/1 atm	Phl
Wones, 1967, Geochim. Cosmo. Acta, <u>31</u>, 2248-2253	V	25°C/1 atm	Phl

Prehnite $Ca_2Al_2Si_3O_{10}(OH)_2$ Pre

Reference	Data type	Range (Temperature/pressure)	Phases studied
Perkins & others, 1980, Geochim. Cosmo. Acta, 44, 61-84	Cp	200-298 K/1 atm	Pre
Perkins & others, 1980, Geochim. Cosmo. Acta, 44, 61-84	Cp	298-800 K/1 atm	Pre
Perkins & others, 1980, Geochim. Cosmo. Acta, 44, 61-84	S	298.15 K/1 atm	Pre
Liou, 1971, Am. Min., 56, 507-531	G	708-828 K/1974-5527 bars	Ano+Wol+H_2O-Pre
Liou, 1971, Am. Min., 56, 507-531	V	25°C/1 atm	Pre

Pyrite FeS_2 Pyt

Reference	Data type	Range (Temperature/pressure)	Phases studied
Gronvold & Westrum, 1962, Inorg. Chem., 1, 36-48	Cp	4.6-346 K/1 atm	Pyt
Gronvold & Westrum, 1976, J. Chem. Thermo., 8, 1039-1048	Cp	350-770 K/1 atm	Pyt
Coughlin, 1950, J. Am. Chem. Soc., 72, 5445-5448	H_T-H_R	298-980 K/1 atm	Pyt
Kelley, 1960, US Bur. Mines Bull. 584, 232 p	H_T-H_R	400-1000 K/1 atm	Pyt
Gronvold & Westrum, 1962, Inorg. Chem., 1, 36-48	S	298.15 K/1 atm	Pyt
Kelley & King, 1961, US Bur. Mines Bull. 592, 149 p	S	298.15 K/1 atm	Pyt
Kullerup & Yoder, 1959, Econ. Geol., 54, 533-572	V	25°C/1 atm	Pyt
Arnold, 1962, Econ. Geol., 75, 72-90	a	325-736°C/1 atm	Pyo+Pyt(FeS-FeS_2 join)
Toulmin & Barton, 1964, Geochim. Cosmo. Acta, 28, 641-671	a	305-490°C/1 atm	Pyo+Pyt(FeS-FeS_2 join)
Toulmin & Barton, 1964, Geochim. Cosmo. Acta, 28, 641-671	a	305-654°C/1 atm	Pyo+Pyt(FeS-FeS_2 join)

Pyrope $Mg_3Al_2Si_3O_{12}$ - Garnet group

Important solid solution

(Mg,Fe)	Pyrope - Almandine join
(Mg,Ca)	Pyrope - Grossular join

Reference	Data type	Range (Temperature/pressure)	Phases studied
Haselton & Westrum, 1980, Geochim. Cosmo. Acta, 44, 701-709	Cp	8-345 K/1 atm	Pyp
Kolesnik & others, 1977, Geokhim., 533-541	Cp		Pyp
Thompson & others, 1977, EOS, 58, 523	Cp	350-1000 K/1 atm	Pyp
Kisleva & others, 1972, Geochem. Int., 9, 1087	H_T-H_R	298-1100 K/1 atm	Pyp
Haselton & Westrum, 1980, Geochim. Cosmo. Acta, 44, 701-709	S	298.15 K/1 atm	Pyp
Kolesnik & others, 1977, Geokhim., 533-541	S	298.15 K/1 atm	Pyp
Charlu & others, 1975, Geochim. Cosmo. Acta, 39, 1487-1497	H	970 K/1 atm	Pyp=Per+Cor+Qzb
Hensen & Essene, 1971, Cont. Min. Pet., 30, 72-83	G	1000-1400°C/14400-19800 bars	Ens+Sil-Pyp+Qza
Staudigel & Schreyer, 1977, Cont. Min. Pet., 61, 187-198	G	870-900°C/22000-35000 bars	Cln=Pyp+For+Spl+H_2O
Staudigel & Schreyer, 1977, Cont. Min. Pet., 61, 187-198	G	900-970°C/20000-21000 bars	Pyp+For=Ens+Spl
Hazen & Finger, 1978, Am. Min., 63, 297-303	V	25°C/1-56000 bars	Pyp
Levien & others, 1979, Am. Min., 64, 805-808	V	24°C/1-49600 bars	Pyp
Lieberman & Gondall, 1952, J. Am. Ceram. Soc., 35, 304-308	V	293-343 K/1 atm	Pyp
Meagher, 1975, Am. Min., 60, 218-228	V	25°C/1 atm	Pyp
Sato & others, 1978, JGR, 83, 335-338	V	25°C/8200-100900 bars	Pyp
Newton & others, 1977, Geochim. Cosmo. Acta, 41, 369-377	dH/dX	970 K/1 atm	Gro+Pyp($Ca_3Al_2Si_3O_{12}$-$Mg_3Al_2Si_3O_{12}$ join)
Newton & others, 1977, Geochim. Cosmo. Acta, 41, 369-377	dV/dX	25°C/1 atm	Gro+Pyp($Ca_3Al_2Si_3O_{12}$-$Mg_3Al_2Si_3O_{12}$ join)

Pyrophyllite $Al_2Si_4O_{10}(OH)_2$

Reference	Data type	Range (Temperature/pressure)	Phases studied
Krupka & others, 1979, Am. Min., 64, 86-101	Cp	335-680 K/1 atm	Pyr
Robie & others, 1976, USGS J. Res., 4, 631-644	Cp	200-370 K/1 atm	Pyr
Robie & others, 1976, USGS J. Res., 4, 631-644	S	298.15 K/1 atm	Pyr
Haas & Holdaway, 1973, AJS, 273, 449-464	G	618-722 K/2400-7000 bars	Pyr+Dia-And+H_2O
Haas & Holdaway, 1973, AJS, 273, 449-464	G	643-737 K/2400-7000 bars	And+Qza+H_2O=Pyr
Hemley & others, 1980, Econ. Geol., 75, 210-228	G	473-573 K/1000 bars	Kao+Qza=Pyr+H_2O
Hemley & others, 1980, Econ. Geol., 75, 210-228	G	523-598 K/1000 bars	Dia+Qza=Pyr
Hemley & others, 1980, Econ. Geol., 75, 210-228	G	613-673 K/1000 bars	And+Qza+H_2O=Pyr
Kerrick, 1968, AJS, 266, 204-214	G	668-718 K/1800-3900 bars	And+Qza+H_2O=Pyr
Nitsch, 1972, Cont. Min. Pet., 34, 116-134	G	310-390°C/4000-7000 bars	Ccl+Pyr+H_2O-Law+Qza+CO_2
Nitsch, 1972, Cont. Min. Pet., 34, 116-134	G	340-385°C/4000-5000 bars	Law=Zoi+Kya+Pyr+H_2O
Nitsch, 1972, Cont. Min. Pet., 34, 116-134	G	370-430°C/7000 bars	Law+Qza=Zoi+Pyr+H_2O
Krupka & others, 1979, Am. Min., 64, 86-101	V	25°C/1 atm	Pyr
Taylor & Bell, 1970, Carn. Inst. Wash. Yb., 193-194	V	22-402°C/1 atm	Pyr

Pyrrhotite $Fe_{1-x}S$, x = 0-0.125

Reference	Data type	Range (Temperature/pressure)	Phases studied
Gronvold & others, 1959, J. Chem. Phys., 30, 528-531	Cp	5-350 K/1 atm	Pyo
Coughlin, 1950, J. Am. Chem. Soc., 72, 5445-5448	H_T-H_R	298-1488 K/1 atm	Pyo
Kelley, 1960, US Bur. Mines Bull. 584, 232 p	H_T-H_R	350-2000 K/1 atm	Pyo
Gronvold & others, 1959, J. Chim. Phys., 30, 528-531	S	298.15 K/1 atm	Pyo
Kelley & King, 1961, US Bur. Mines Bull. 592, 149 p	S	298.15 K/1 atm	Pyo
Adams & King, 1964, US Bur. Mines Rpt. Inv. 6495, 10 p	H	73.7°C/1 atm	Pyo
Fizeau, 1888, Ann. pour l'an Paris, Bur. longitudes	V	293-343 K/1 atm	Pyo
Arnold, 1962, Econ. Geol., 75, 72-90	a	325-736°C/1 atm	Pyo+Pyt($FeS-FeS_2$ join)
Toulmin & Barton, 1964, Geochim. Cosmo. Acta, 28, 641-671	a	305-490°C/1 atm	Pyo+Pyt($FeS-FeS_2$ join)
Toulmin & Barton, 1964, Geochim. Cosmo. Acta, 28, 641-671	a	305-654°C/1 atm	Pyo+Pyt($FeS-FeS_2$ join)
Toulmin & Barton, 1964, Geochim. Cosmo. Acta, 28, 641-671	a	389-909°C/1 atm	Pyo($FeS-FeS_2$ join)
Haraldsen, 1941, Z. Anorg. Chem., 246, 169-194	dV/dX	25°C/1 atm	Pyo($FeS-FeS_2$ join)
Toulmin & Barton, 1964, Geochim. Cosmo. Acta, 28, 641-671	dV/dX	25°C/1 atm	Pyo($FeS-FeS_2$ join)

Quartz - alpha, beta SiO_2 - polymorph with Tridymite, Cristobalite, Coesite, Stishovite Qza,Qzb

Reference	Data type	Range (Temperature/pressure)	Phases studied
Chase & others, 1974, J. Phys. Chem. Ref. Data, 3, 311-480	Cp	298-2000 K/1 atm	Qza
Chase & others, 1975, J. Phys. Chem. Ref. Data, 4, 1-176	Cp	298-2000 K/1 atm	Qza
Stull & Prophet, 1971, US NBS NSRDS-NBS 37	Cp	298-2000 K/1 atm	Qza
CODATA Task Group, 1978, CODATA Bull., 28, 1-16	S		Qza
Anderson & Kleppa, 1969, AJS, 267, 285-290	H	974 K/1 atm	Kya=Cor+Qza
Anderson & others, 1977, AJS, 277, 585-593	H	973 K/1 atm	Cor+Qza=And
Barany & Kelley, 1961, US Bur. Mines Rpt. Inv. 5810, 6 p	H	346.85 K/1 atm	Hal+H_2O-Qza+Gib
Barany & Kelley, 1961, US Bur. Mines Rpt. Inv. 5810, 6 p	H	346.85 K/1 atm	Kao+H_2O=Qza+Gib
Barany & Kelley, 1961, US Bur. Mines Rpt. Inv. 5825, 13 p	H	346.85 K/1 atm	Dic+H_2O-Qza+Hib
Barany, 1963, US Bur. Mines Rpt. Inv. 6251, 9 p	H	25°C/1 atm	Tlc=Per+Qza+H_2O
Barany, 1966, US Bur. Mines Rpt. Inv. 6784, 8 p	H	346.85 K/1 atm	Wol-Qza+Lme
CODATA Task Group, 1978, CODATA Bull., 28, 1-16	H		Qza
Charlu & others, 1975, Geochim. Cosmo. Acta, 39, 1487-1497	H	970 K/1 atm	Ens=Per+Qzb
Charlu & others, 1975, Geochim. Cosmo. Acta, 39, 1487-1497	H	970 K/1 atm	Pyp=Per+Cor+Qzb
Charlu & others, 1978, Geochim. Cosmo. Acta, 42, 367-375	H	970 K/1 atm	Ano=Lme+Cor+Qza
Charlu & others, 1978, Geochim. Cosmo. Acta, 42, 367-375	H	970 K/1 atm	Cts=Lme+Cor+Qza
Charlu & others, 1978, Geochim. Cosmo. Acta, 42, 367-375	H	970 K/1 atm	Gro=Lme+Cor+Qzb
Charlu & others, 1978, Geochim. Cosmo. Acta, 42, 367-375	H	970 K/1 atm	Lme+Qzb-Cwo
Charlu & others, 1978, Geochim. Cosmo. Acta, 42, 367-375	H	970 K/1 atm	Sil=Cor+Qzb
Charlu & others, 1978, Geochim. Cosmo. Acta, 42, 367-375	H	970 K/1 atm	Wol=Qzb+Lme
Charlu & others, 1978, Geochim. Cosmo. Acta, 42, 367-375	H	970 K/1 atm	Dio=Lme+Per+Qzb
King & others, 1967, US Bur. Mines Rpt. Inv. 6962, 19 p	H	25°C/1 atm	For=Per+Qza
King, 1951, J. Am. Chem. Soc., 73, 656-658	H	346.85 K/1 atm	Lar=Qza+Lme
Kracek & Neuvonen, 1952, AJS, Bowen Vol., 293-318	H	347.85 K/1 atm	Ano+H_2O-Lme+Gib+Qza

Kracek & others, 1953, Carn. Inst. Wash. Yb., 69-74	H	74.7°C/1 atm	Dio=Lme+Per+Qza
Navrotsky & Coons, 1976, Geochim. Cosmo. Acta, 40, 1281-1288	H	970 K/1 atm	Dio=Lme+Per+Qzb
Shearer & Kleppa, 1973, J. Inorg. Nuc. Chem., 35, 1073-1078	H	965-1173 K/1 atm	Ens=Per+Qzb
Shearer & Kleppa, 1973, J. Inorg. Nuc. Chem., 35, 1073-1078	H	965-1173 K/1 atm	For=Per+Qzb
Weeks, 1956, J. Geol., 64, 456-472	H	81°C/1 atm	Tre=Ran+Ant+Qza+H_2O
Renz & Wagner, 1961, J. Phys. Chem., 65, 1308-1311	G(emf)	898-1148 K/1 atm	Wol=Qzb+Lme
Birch & LeComte, 1960, AJS, 258, 209-217	G	802-1007°C/21280-26040 bars	Ana=Jad+Qza
Bird & Fawcett, 1973, J. Pet., 14, 415-428	G	634-664°C/8270-9790 bars	Cln+Mus=Phl+Kya+Qza+H_2O
Boettcher, 1970, J. Pet., 11, 337-379	G	853-933 K/4000-5300 bars	Gro+Ano+H_2O=Zoi+Qza
Boettcher, 1970, J. Pet., 11, 337-379	G	893-1053 K/3000-5900 bars	Ano+Wol=Gro+Qzb
Bohlen & others, 1980, Earth Planet. Sci. Lett., 47, 1-10	G	700-850°C/10500-12000 bars	Fes=Fay+Qza
Bohlen & others, 1980, Earth Planet. Sci. Lett., 47, 1-10	G	900-1050°C/12500-15000 bars	Fes=Fay+Qzb
Boyd, 1959, Res. Geochem., 1, 377-396	G	800-880°C/575-2000 bars	Tre=Dio+Ens+Qza+H_2O
Campbell & Fyfe, 1965, AJS, 263, 807-816	G	175-210°C/8.9-19 bars	Anl+Qza=Alb+H_2O
Chatterjee & Johannes, 1974, Cont. Min. Pet., 48, 89-114	G	520-705°C/500-5000 bars	Mus+Qza=San+And+H_2O
Chatterjee & Johannes, 1974, Cont. Min. Pet., 48, 89-114	G	540-720°C/500-6000 bars	Mus+Qza=San+Sil+H_2O
Chatterjee, 1972, Cont. Min. Pet., 34, 288-303	G	470-600°C/1000-5000 bars	Par+Qza=Ana+And+H_2O
Chatterjee, 1972, Cont. Min. Pet., 34, 288-303	G	570-640°C/5000-7000 bars	Par+Qza=Ana+Kya+H_2O
Chernosky & Autio, 1979, Am. Min., 64, 294-303	G	647-742°C/500-3000 bars	Tlc=Ant+Qzb+H_2O
Chernosky & Autio, 1979, Am. Min., 64, 294-303	G	664-775°C/500-2000 bars	Ant=Ens+Qzb+H_2O
Chernosky, 1976, Am. Min., 61, 1145-1155	G	648-744°C/500-2000 bars	Tlc=Ens+Qza+H_2O
Chernosky, 1978, Am. Min., 63, 73-82	G	504-581°C/2000-4000 bars	Cln+Qza=Tlc+Crd+H_2O
Chou, 1978, Am. Min., 63, 690-703	G	600-800°C/2000-4000 bars	Mgt+Qzb=Fay+Oxy
Day, 1971, PhD Thesis, Brown Univ.	G		Fec+San+H_2O=Ann+Sil+Qza
Day, 1973, Am. Min., 58, 255-262	G	580-668°C/1000-3000 bars	Mus+Qza=San+Sil+H_2O
Essene & others, 1972, EOS, 53, 544	G	800-1200°C/20500-31000 bars	Ana=Jad+Qza
Eugster & Wones, 1962, J. Pet., 3, 82-125	G	540-550°C/1035 bars	Ann+Qzb+Irn=San+Fay+Mus+H_2O
Eugster & Wones, 1962, J. Pet., 3, 82-125	G	650-710°C/1035-2070 bars	Ann+Qzb=Hag+San+Fay+H_2O

Goldsmith, 1980, Am. Min., 65, 272-284	G	1100-1400°C/22000-31000 bars	Ano-Gro+Kya+Qza
Gordon & Greenwood, 1970, AJS, 268, 225-242	G	410-522°C/2000 bars	Dol+Qza-Mcc+Tlc+CO_2
Gordon & Greenwood, 1970, AJS, 268, 225-242	G	450-519°C/2000 bars	Dol+Qza-Mcc+Tlc+CO_2
Greenwood, 1963, J. Pet., 4, 317-351	G	694-711°C/2000 bars	Tlc=Ant+Qzb+H_2O
Greenwood, 1963, J. Pet., 4, 317-351	G	703-775°C/2000-2600 bars	Tlc=Ens+Qzb+H_2O
Greenwood, 1963, J. Pet., 4, 317-351	G	750-775°C/2000-2600 bars	Ant=Ens+Qzb+H_2O
Greenwood, 1967, Am. Min., 52, 1669-1680	G	558-595°C/1000-2000 bars	Ccl+Qza-Wol+CO_2
Greenwood, 1967, Am. Min., 52, 1669-1680	G	609-723°C/1000-2000 bars	Ccl+Qzb=Wol+CO_2
Gustafson, 1974, J. Pet., 15, 455-496	G	401-529°C/2000 bars	Hed+Bun-Adr+Mag+Qzb+Hlc
Gustafson, 1974, J. Pet., 15, 455-496	G	748-797°C/500-2000 bars	Adr+Fay-Mag+Wol+Qzb
Gusynin & Ivanov, 1971, Dokl. Akad. Nauk SSSR, 197, 1169-1170	G	490-510°C/1000 bars	Par+Qza-Ana+And+H_2O
Haas & Holdaway, 1973, AJS, 273, 449-464	G	643-737 K/2400-7000 bars	And+Qza+H_2O=Pyr
Harker & Tuttle, 1956, AJS, 254, 239-256	G	600-800°C/300-2400 bars	Ccl+Qzb-Wol+CO_2
Haselton & others, 1978, Geophys. Res. Lett., 5, 753-756	G	1000-1325°C/10000-19000 bars	Cc2+Qzb-Wol+CO_2
Hemley & others, 1961, USGS Prof. Paper 424-D, 338-340	G	330°C/1000 bars	Nmt+Alb-Qza+Par
Hemley & others, 1980, Econ. Geol., 75, 210-228	G	473-573 K/1000 bars	Boe+Qza+H_2O-Kao
Hemley & others, 1980, Econ. Geol., 75, 210-228	G	473-573 K/1000 bars	Dia+Qza+H_2O=Kao
Hemley & others, 1980, Econ. Geol., 75, 210-228	G	473-573 K/1000 bars	Kao+Qza-Pyr+H_2O
Hemley & others, 1980, Econ. Geol., 75, 210-228	G	523-598 K/1000 bars	Dia+Qza-Pyr
Hemley & others, 1980, Econ. Geol., 75, 210-228	G	623-663 K/1000 bars	Dia+Qza=And+H_2O
Hemley & others, 1980, Econ. Geol., 75, 210-228	G	723-773 K/1000 bars	Cor+Qza-And
Hemley & others, 1980, Econ. Geol., 75, 210-228	G	613-673 K/1000 bars	And+Qza+H_2O=Pyr
Hensen & Essene, 1971, Cont. Min. Pet., 30, 72-83	G	1000-1400°C/14400-19800 bars	Ens+Sil=Pyp+Qza
Hewitt, 1976, EOS, 57, 1020	G	650-850°C/1000 bars	Mgt+Qzb=Fay+Oxy
Hewitt, D., 1973, Am. Min., 58, 785-791	G	448-610°C/2000-7000 bars	Mus+Ccl+Qza-San+Ano+CO_2+H_2O
Hewitt, D., 1973, Am. Min., 58, 785-791	G	539-540°C/6000 bars	Mus+Ccl+Qza=San+Zoi+CO_2+H_2O
Holdaway & Lee, 1977, Cont. Min. Pet., 63, 175-198	G	624-775°C/2700-3800 bars	Fec=Alm+Sil+Qza+H_2O
Holdaway & Lee, 1977, Cont. Min. Pet., 63, 175-198	G	641-710°C/1900-2800 bars	Fec+San+H_2O-Ann+Sil+Qza

Holdaway & Lee, 1977, Cont. Min. Pet., 63, 175-198	G	774-776°C/2700-2900 bars	Fec=Hcy+Qza+H_2O
Huckenholz, 1974, Carn. Inst. Wash. Yb., 411-426	G	848-858 K/1000-3000 bars	Ano+Wol-Gro+Qza
Huckenholz, 1974, Carn. Inst. Wash. Yb., 411-426	G	888-958 K/4000 bars	Ano+Wol=Gro+Qzb
Johannes & others, 1971, Cont. Min. Pet., 32, 24-38	G	600°C/15700-16800 bars	Ana=Jad+Qza
Johannes, 1969, AJS, 267, 1083-1104	G	300-600°C/330-7000 bars	Tlc+CO_2=Qza+Mag+H_2O
Juan & Lo, 1971, Proc. Geol. Soc. China, 14, 34-44	G	292-469°C/690-1380 bars	Wai=Ano+Qza+H_2O
Kerrick, 1968, AJS, 266, 204-214	G	668-718 K/1800-3900 bars	And+Qza+H_2O-Pyr
Kerrick, 1972, AJS, 272, 946-958	G	600-610°C/2000 bars	Mus+Qza-San+And+H_2O
Lindsley, 1965, Carn. Inst. Wash. Yb., 148-150	G	1000-1100°C/15500-17000 bars	Fes=Fay+Qza
Lindsley, 1965, Carn. Inst. Wash. Yb., 148-150	G	1275-1280°C/1700-1750 bars	Pfs=Fay+Qza
Liou, 1970, Cont. Min. Pet., 27, 259-282	G	325-393°C/500-5000 bars	Wai=Ano+Qza+H_2O
Liou, 1971, Cont. Min. Pet., 31, 171-177	G	175-200°C/3000-5000 bars	Stl=Lau+Qza+H_2O
Liou, 1971, J. Pet., 12, 379-411	G	194-249°C/2800-3500 bars	Lau-Law+Qza+H_2O
Liou, 1971, J. Pet., 12, 379-411	G	297-381°C/3200-4350 bars	Wai=Law+Qza
Liou, 1971, Lithos, 4, 389-402	G	178-210°C/2000-5000 bars	Ana+Qza-Alb+H_2O
Liou, 1973, J. Pet., 14, 381-413	G	630-762°C/2000-5000 bars	Ept+Mgt-(Gro+Adr+Alm)+Ano+Qza+Hem+H_2O
Liou, 1974, Am. Min., 59, 1016-1025	G	570-610°C/500-2000 bars	Adr+Qza+Fay-Hed+Wol
Liou, 1974, Am. Min., 59, 1016-1025	G	621-683°C/500-2000 bars	Adr+Qza+Nic-Hed+Wol+Bun
Lo, 1978, Proc. Geol. Soc. China, 21, 25-33	G	258-308°C/690-2069 bars	Ept=Wai+Qza+H_2O
Metz & Winkler, 1963, Geochim. Cosmo. Acta, 27, 431-457	G	440-510°C/2000 bars	Dol+Qza-Hcc+Tlc+CO_2
Newton & Smith, 1967, J. Geol., 75, 268-286	G	500-600°C/13500-16900 bars	Ana=Jad+Qza
Newton, 1966, AJS, 264, 204-222	G	803-923 K/1100-2000 bars	Ano+Wol-Gro+Qza
Newton, 1966, AJS, 264, 204-222	G	973-1023 K/4700-5700 bars	Ano+Wol=Gro+Qzb
Nitsch, 1968, Naturw., 55, 388	G	160-210°C/7000 bars	Heu=Law+Qza+H_2O
Nitsch, 1968, Naturw., 55, 388	G	345°C/2500-3500 bars	Lau-Law+Qza+H_2O
Nitsch, 1972, Cont. Min. Pet., 34, 116-134	G	310-390°C/4000-7000 bars	Ccl+Pyr+H_2O=Law+Qza+CO_2
Nitsch, 1972, Cont. Min. Pet., 34, 116-134	G	370-430°C/7000 bars	Law+Qza=Zoi+Pyr+H_2O
Nitsch, 1974, For. Min., 51, 34-35	G	325-445°C/4000-10000 bars	Law-Zoi+Mar+Qza+H_2O

Richardson, 1968, J. Pet., 9, 467-488	G		Fec=Alm+Sil+Qza+H_2O
Richardson, 1968, J. Pet., 9, 467-488	G		Fec=Hcy+Qza+H_2O
Smith, 1971, AJS, 271, 370-382	G	1075-1100°C/15500-18000 bars	Fes=Fay+Qzb
Smith, 1971, AJS, 271, 370-382	G	750-900°C/11000-15000 bars	Fes=Fay+Qza
Storre & Nitsch, 1974, Cont. Min. Pet., 43, 1-24	G	763-833 K/4000-5000 bars	Ano+And+H_2O-Mar+Qzb
Storre & Nitsch, 1974, Cont. Min. Pet., 43, 1-24	G	788-833 K/4000-5000 bars	Ano+And+H_2O-Mar+Qza
Storre & Nitsch, 1974, Cont. Min. Pet., 43, 1-24	G	803-933 K/4000-5000 bars	Ano+Kya+H_2O=Mar+Qza
Strens, 1968, Min. Mag., 36, 864-867	G	770-823 K/2000 bars	Gro+Ano+H_2O=Zoi+Qza
Taylor & Liou, 1978, Am. Min., 63, 378-393	G	498-600°C/2000 bars	Qza+Ccl+Hem=Adr+CO_2
Thompson, 1970, AJS, 269, 267-275	G	250°C/2500-3000 bars	Lau=Law+Qza+H_2O
Thompson, 1970, AJS, 269, 267-275	G	300-357°C/1000-6000 bars	Lau=Ano+Qza+H_2O
Thompson, 1971, AJS, 271, 79-92	G	150-200°C/2000-5500 bars	Anl+Qza=Alb+H_2O
Thompson, 1976, Prog. Exp. Pet., Ser. D(6-1976), 12-13	G	390-465°C/500-2000 bars	Ccl+And+Qza-Ano+CO_2
Wones & Dodge, 1977, Thermo. in Geol., 229-247	G	726-774°C/400 bars	Tre=Dio+Ens+Qza+H_2O
Wones & Dodge, 1977, Thermo. in Geol., 229-247	G	740-755°C/2000 bars	Tre+San-Phl+Dio+Qza
Wones & Dodge, 1977, Thermo. in Geol., 229-247	G	830-840°C/400-500 bars	Phl+Qzb-San+Ens+H_2O
Wones & Gilbert, 1969, AJS, 267-A, 480-488	G	594-803°C/800-2000 bars	Mgt+Qzb=Fay+Oxy
Wood, 1976, Prog. Exp. Pet., Ser. D(6-1976), 17-19	G	750-790°C/300-470 bars	Phl+Qzb-San+Ens+H_2O
Yoder, 1950, EOS, 31, 827-835	G	572-815°C/1-10000 bars	Qza=Qzb
Adams & others, 1919, J. Am. Chem. Soc., 41, 12-42	V	25°C/1960-12000 bars	Qza
Jay, 1933, Proc. Roy. Soc. Lond., Ser. A, 142, 237-247	V	18-579°C/1 atm	Qza
Jay, 1933, Proc. Roy. Soc. Lond., Ser. A, 142, 237-247	V	590-730°C/1 atm	Qzb
Olinger & Halleck, 1976, JGR, 81, 5711-5714	V	25°C/33800-120700 bars	Qza
Robie & others, 1967, USGS Bull. 1248, 87 p	V	25°C/1 atm	Qza
Vaidya & others, 1973, JGR, 78, 6893-6898	V	25°C/5000-45000 bars	Qza

Sanidine $\mathrm{KAlSi_3O_8}$ - Feldspar group

Al,Si disordered in tetrahedral sites

Important solid solution

(K,Na) Sanidine - Analbite join (alkali Feldspar series)

(AlSi disorder, AlSi order Sanidine - Microcline join (K-Feldspar series)
in tetrahedral sites)

Reference	Data type	Range (Temperature/pressure)	Phases studied
B.S. Hemingway & others, USGS, unpub. data, 1979	Cp	340-978 K/1 atm	San
Openshaw & others, 1976, USGS J. Res., 4, 195-204	Cp	16-376 K/1 atm	San
Kelley, 1960, US Bur. Mines Bull. 584, 232 p	H_T-H_R	400-1400 K/1 atm	San
Openshaw & others, 1976, USGS J. Res., 4, 195-204	S	298.15 K/1 atm	San
B.S. Hemingway & others, USGS, unpub. data, 1979	H	49.7°C/1 atm	San
Hovis, 1972, Proc. NATO Adv. Study Inst., 114-144	H	49.7°C/1 atm	San
Chatterjee & Johannes, 1974, Cont. Min. Pet., 48, 89-114	G	520-705°C/500-5000 bars	$\mathrm{Mus+Qza=San+And+H_2O}$
Chatterjee & Johannes, 1974, Cont. Min. Pet., 48, 89-114	G	540-720°C/500-6000 bars	$\mathrm{Mus+Qza-San+Sil+H_2O}$
Chatterjee & Johannes, 1974, Cont. Min. Pet., 48, 89-114	G	600-800°C/1000-8000 bars	$\mathrm{Mus=San+Cor+H_2O}$
Day, 1971, PhD Thesis, Brown Univ.	G		$\mathrm{Fec+San+H_2O=Ann+Sil+Qza}$
Day, 1973, Am. Min., 58, 255-262	G	580-668°C/1000-3000 bars	$\mathrm{Mus+Qza=San+Sil+H_2O}$
Eugster & Wones, 1962, J. Pet., 3, 82-125	G	540-550°C/1035 bars	$\mathrm{Ann+Qzb+Irn=San+Fay+Wus+H_2O}$
Eugster & Wones, 1962, J. Pet., 3, 82-125	G	610-640°C/1035-2070 bars	$\mathrm{Ann+Bun-San+Mag+Nil+H_2O}$
Eugster & Wones, 1962, J. Pet., 3, 82-125	G	650-710°C/1035-2070 bars	$\mathrm{Ann+Qzb=Mag+San+Fay+H_2O}$
Eugster & Wones, 1962, J. Pet., 3, 82-125	G	775-790°C/1035 bars	$\mathrm{Ann+Mag=San+Wus+H_2O}$
Hewitt, D., 1973, Am. Min., 58, 785-791	G	448-610°C/2000-7000 bars	$\mathrm{Mus+Ccl+Qza-San+Ano+CO_2+H_2O}$
Hewitt, D., 1973, Am. Min., 58, 785-791	G	539-540°C/6000 bars	$\mathrm{Mus+Ccl+Qza-San+Zoi+CO_2+H_2O}$
Hewitt, D., 1975, Am. Min., 60, 391-397	G	460-681°C/2000-8000 bars	$\mathrm{Phl+Ccl+Qza-Tre+San+CO_2+H_2O}$

Holdaway & Lee, 1977, Cont. Min. Pet., 63, 175-198	G	641-710°C/1900-2800 bars	Fec+San+H_2O-Ann+Sil+Qza
Hoschek, 1973, Cont. Min. Pet., 39, 231-237	G	495-635°C/4000-6000 bars	Phl+Cal+Qza-Tre+San+CO_2+H_2O
Kerrick, 1972, AJS, 272, 946-958	G	600-610°C/2000 bars	Mus+Qza=San+And+H_2O
Wones & Dodge, 1977, Thermo. in Geol., 229-247	G	740-755°C/2000 bars	Tre+San-Phl+Dio+Qza
Wones & Dodge, 1977, Thermo. in Geol., 229-247	G	830-840°C/400-500 bars	Phl+Qzb=San+Ens+H_2O
Wood, 1976, Prog. Exp. Pet., Ser. D(6-1976), 17-19	G	750-790°C/300-470 bars	Phl+Qzb-San+Ens+H_2O
Hovis, 1972, Proc. NATO Adv. Study Inst., 114-144	V	25°C/1 atm	San
Openshaw & others, 1976, USGS J. Res., 4, 195-204	V	25°C/1 atm	San
Wones & Dodge, 1977, Thermo. in Geol., 229-247	V	25°C/1 atm	San
Hovis & Waldbaum, 1977, Am. Min., 62, 680-686	dH/dX	49.7°C/1 atm	San+Ana($KAlSi_3O_8$-$NaAlSi_3O_8$ join)
Waldbaum & Robie, 1971, Z. Krist., 134, 381-420	dH/dX	49.7°C/1 atm	San+Ana($KAlSi_3O_8$-$NaAlSi_3O_8$ join)
Hovis, 1977, Am. Min., 62, 672-679	dV/dX	25°C/1 atm	San+Ana($KAlSi_3O_8$-$NaAlSi_3O_8$ join)
Orville, 1967, Am. Min., 52, 55-86	dV/dX	25°C/1 atm	San+Ana($KAlSi_3O_8$-$NaAlSi_3O_8$ join)

Reference	Data type	Range (Temperature/pressure)	Phases studied
Chase & others, 1974, J. Phys. Chem. Ref. Data, 3, 311-480	Cp		H_2O
Chase & others, 1975, J. Phys. Chem. Ref. Data, 4, 1-176	Cp		H_2O
Stull & Prophet, 1971, US NBS NSRDS-NBS 37	Cp		H_2O
Wolley, 1980, Cont. 9th Int. Conf. Prop. Steam, Munich	Cp	50-4000 K/1 atm	H_2O
Haar & others, 1980, Cont. 9th Int. Conf. Prop. Steam, Munich	S	0-900°C/0-10000 bars	H_2O
CODATA Task Group, 1978, CODATA Bull., 28, 1-16	S		H_2O
Wolley, 1980, Cont. 9th Int. Conf. Prop. Steam, Munich	S	50-4000 K/1 atm	H_2O
CODATA Task Group, 1978, CODATA Bull., 28, 1-16	H		H_2O
Haar & others, 1980, Cont. 9th Int. Conf. Prop. Steam, Munich	H	0-900°C/0-10000 bars	H_2O
Wolley, 1980, Cont. 9th Int. Conf. Prop. Steam, Munich	H	50-4000 K/1 atm	H_2O
Haar & others, 1980, Cont. 9th Int. Conf. Prop. Steam, Munich	G	0-900°C/0-10000 bars	H_2O
Greenwood & Barnes. 1966, GSA Mem., 97, 385-400	P-V-T	12-750°C/25-2000 bars	$CO_2+H_2O(CO_2-H_2O$ join)
Greenwood, 1969, AJS, 267-A, 191-208	P-V-T	450-800°C/1-500 bars	$CO_2+H_2O(CO_2-H_2O$ join)
Haar & others, 1980, Cont. 9th Int. Conf. Prop. Steam, Munich	P-V-T	0-900°C/0-10000 bars	H_2O
Liley, 1956, Rpt. Brit. Admir. DEMR/EN/32/16/1/56	P-V-T		$CO_2+H_2O(CO_2-H_2O$ join)
Powell & others, 1979, Prog. Astronau. Aeronau., 66, 325-348	P-V-T	0-900°C/0-10000 bars	$CO_2+H_2O(CO_2-H_2O$ join)
Takenouchi & Kennedy, 1964, AJS, 262, 1055-1074	P-V-T	110-350°C/1-1600 bars	$CO_2+H_2O(CO_2-H_2O$ join)

Stilbite $CaAl_2Si_7O_{18} \cdot 7H_2O$ - Zeolite group

Important solid solution

(Ca,Na_2)	Stilbite - $Na_2Al_2Si_7O_{18} \cdot 7H_2O$ join
$(CaAl,NaSi)$	Stilbite - $NaAlSi_8O_{18} \cdot 7H_2O$ join
$(H_2O,[])$	Stilbite - $CaAl_2Si_7O_{18} \cdot 7[]$ join

Reference	Data type	Range (Temperature/pressure)	Phases studied
Liou, 1971, Cont. Min. Pet., 31, 171-177	G	175-200°C/3000-5000 bars	Stl=Lau+Qz+H_2O
Liou, 1971, Cont. Min. Pet., 31, 171-177	V	25°C/1 atm	Stl

Talc $Mg_3Si_4O_{10}(OH)_2$

Reference	Data type	Range (Temperature/pressure)	Phases studied
Krupka & others, 1977, GSA Abs. Prog., 9, 1060; Krupka, unpubl.	Cp	350-800 K/1 atm	Tlc
Robie & Stout, 1963, J. Phys. Chem., 67, 2252-2256	S	298.15 K/1 atm	Tlc
Barany, 1963, US Bur. Mines Rpt. Inv. 6251, 9 p	H	25°C/1 atm	Tlc=Per+Qza+H_2O
Chernosky & Autio, 1979, Am. Min., 64, 294-303	G	647-742°C/500-3000 bars	Tlc=Ant+Qzb+H_2O
Chernosky, 1976, Am. Min., 61, 1145-1155	G	600-706°C/500-4000 bars	Tlc+For=Ens+H_2O
Chernosky, 1976, Am. Min., 61, 1145-1155	G	648-744°C/500-2000 bars	Tlc=Ens+Qza+H_2O
Chernosky, 1978, Am. Min., 63, 73-82	G	504-581°C/2000-4000 bars	Cln+Qza=Tlc+Crd+H_2O
Evans & others, 1976, Schweiz. Min. Pet. Mitt., 56, 79-93	G	480-660°C/2000-15000 bars	Atg=For+Tlc+H_2O
Gordon & Greenwood, 1970, AJS, 268, 225-242	G	410-522°C/2000 bars	Dol+Qza=Hcc+Tlc+CO_2
Gordon & Greenwood, 1970, AJS, 268, 225-242	G	450-519°C/2000 bars	Dol+Qza=Hcc+Tlc+CO_2
Greenwood, 1963, J. Pet., 4, 317-351	G	662-712°C/2000-2600 bars	Tlc+For=Ens+H_2O
Greenwood, 1963, J. Pet., 4, 317-351	G	663-679°C/1000-4000 bars	For+Tlc=Ant+H_2O
Greenwood, 1963, J. Pet., 4, 317-351	G	694-711°C/2000 bars	Tlc=Ant+Qzb+H_2O
Greenwood, 1963, J. Pet., 4, 317-351	G	703-775°C/2000-2600 bars	Tlc=Ens+Qzb+H_2O
Hemley & others, 1977, AJS, 277, 322-351	G	450-600°C/1000 bars	For+Hsi=Tlc+H_2O
Hemley & others, 1977, AJS, 277, 322-351	G	90-450°C/1 atm-2000 bars	Chr+Hsi=Tlc+H_2O
Hemley & others, 1977, AJS, 277, 353-383	G	300-450°C/1000 bars	Atg+Hsi=Tlc+H_2O
Hemley & others, 1977, AJS, 277, 353-383	G	550-640°C/1000 bars	For+Hsi=Tlc+H_2O
Hemley & others, 1977, AJS, 277, 353-383	G	640-670°C/1000 bars	Ant+Hsi=Tlc+H_2O
Hemley & others, 1977, AJS, 277, 353-383	G	649-690°C/1000 bars	Ens+Hsi=Tlc+H_2O
Johannes, 1969, AJS, 267, 1083-1104	G	300-600°C/330-7000 bars	Tlc+CO_2=Qza+Mag+H_2O
Johannes, 1969, AJS, 267, 1083-1104	G	340-490°C/1000-4000 bars	Chr+CO_2=Tlc+Mag+H_2O
Johannes, 1969, AJS, 267, 1083-1104	G	450-660°C/500-7000 bars	For+H_2O+CO_2=Tlc+Mag

Metz & Winkler, 1963, Geochim. Cosmo. Acta, 27, 431-457	G	440-510°C/2000 bars	Dol+Qz=Cc+Tlc+CO$_2$
Chernosky & Autio, 1979, Am. Min., 64, 294-303	V	25°C/1 atm	Tlc
Hemley & others, 1977, AJS, 277, 322-315	V	25°C/1 atm	Tlc
Koishi & Gillies, 1979, Am. Min., 64, 211-214	V	25-600°C/1 atm	Tlc
Stemple & Brindley, 1960, J. Am. Ceram. Soc., 43, 34-42	V	25°C/1 atm	Tlc
Vaidya & others, 1973, JGR, 78, 6893-6898	V	25°C/5000-45000 bars	Tlc

Tremolite $Ca_2Mg_5Si_8O_{22}(OH)_2$ - Amphibole group

Important solid solution

(Mg,Fe)	Tremolite - $Ca_2Fe_5Si_8O_{22}(OH)_2$ join
(MgSi,Al_2)	Tremolite - $Ca_2Mg_3Al_4Si_6O_{22}(OH)_2$ join
(Si,NaAl)	Tremolite - $NaCa_2Mg_5AlSi_7O_{22}(OH)_2$ join

Reference	Data type	Range (Temperature/pressure)	Phases studied
Krupka & others, 1977, GSA Abs. Prog., 9, 1060; Krupka, unpubl.	Cp	350-800 K/1 atm	Tre
Robie & Stout, 1963, J. Phys. Chem., 67, 2252-2256	Cp	12-305 K/1 atm	Tre
Robie & Stout, 1963, J. Phys. Chem., 67, 2252-2256	S	298.15 K/1 atm	Tre
Weeks, 1956, J. Geol., 64, 456-472	H	81°C/1 atm	Tre-Ran+Ant+Qza+H_2O
Boyd, 1959, Res. Geochem., 1, 377-396	G	800-880°C/575-2000 bars	Tre=Dio+Ens+Qza+H_2O
Hewitt, D., 1975, Am. Min., 60, 391-397	G	460-681°C/2000-8000 bars	Phl+Ccl+Qza-Tre+San+CO_2+H_2O
Hoschek, 1973, Cont. Min. Pet., 39, 231-237	G	495-635°C/4000-6000 bars	Phl+Ccl+Qza-Tre+San+CO_2+H_2O
Metz, 1967, Geochim. Cosmo. Acta, 31, 1517-1532	G	450-550°C/500-1000 bars	Tre+Dol-For+Hcc+CO_2+H_2O
Wones & Dodge, 1977, Thermo. in Geol., 229-247	G	726-774°C/400 bars	Tre=Dio+Ens+Qza+H_2O
Wones & Dodge, 1977, Thermo. in Geol., 229-247	G	740-755°C/2000 bars	Tre+San-Phl+Dio+Qza
Adams & Williamson, 1923, J. Franklin Inst., 195, 475-529	V	25°C/2000-12000 bars	Tre
Stemple & Brindley, 1960, J. Am. Ceram. Soc., 43, 34-42	V		Tre
Sueno & others, 1973, Am. Min., 58, 649-664	V	24-700°C/1 atm	Tre
Wones & Dodge, 1977, Thermo. in Geol., 229-247	V	25°C/1 atm	Tre
Zussman, 1959, Acta Cryst., 12, 309-312	V		Tre

Wairakite $CaAl_2Si_4O_{12} \cdot 2H_2O$ - Zeolite group

Important solid solution

(Ca,Na_2) Wairakite - Analcite join

$(H_2O, [\,])$ Wairakite - $CaAl_2Si_4O_{12} \cdot 2[\,]$ join

Reference	Data type	Range (Temperature/pressure)	Phases studied
Juan & Lo, 1971, Proc. Geol. Soc. China, 14, 34-44	G	250-278°C/890-1380 bars	$Lau=Wai+H_2O$
Juan & Lo, 1971, Proc. Geol. Soc. China, 14, 34-44	G	292-469°C/690-1380 bars	$Wai=Ano+Qza+H_2O$
Liou, 1970, Cont. Min. Pet., 27, 259-282	G	325-393°C/500-5000 bars	$Wai=Ano+Qza+H_2O$
Liou, 1971, J. Pet., 12, 379-411	G	259-330°C/1000-6000 bars	$Lau=Wai+H_2O$
Liou, 1971, J. Pet., 12, 379-411	G	297-381°C/3200-4350 bars	Wai=Law+Qza
Lo, 1978, Proc. Geol. Soc. China, 21, 25-33	G	258-308°C/690-2069 bars	$Fpi=Wai+Qza+H_2O$
Liou, 1970, Cont. Min. Pet., 27, 259-282	V	25°C/1 atm	Wai

Wollastonite $CaSiO_3$ - Pyroxene group

Important solid solution

(Ca,Fe) Wollastonite - Clinoferrosilite join

($CaSi,Al_2$) Wollastonite - Ca-Al Clinopyroxene join

Reference	Data type	Range (Temperature/pressure)	Phases studied
Cristescu & Simon, 1934, Z. Phys. Chem., 258, 273-282	Cp	200-210 K/1 atm	Wol
Cristescu (in Wagner, 1932, Z. Anorg. Allg. Chem., 208, 1-22)	Cp	200-304 K/1 atm	Wol
Gronow & Schwiete, 1933, Z. Anorg. Allg. Chem., 216, 185-195	H_T-H_R	573-1373 K/1 atm	Wol
Roth & Bertram, 1929, Z. Elek. Angew. Phys. Chem., 35, 279-384	H_T-H_R	323-1157 K/1 atm	Wol
Southard, 1941, J. Am. Chem. Soc., 63, 3142-3146	H_T-H_R	485-1423 K/1 atm	Wol
Wagner, 1932, Z. Anorg. Allg. Chem., 208, 1-22	H_T-H_R	566-1383 K/1 atm	Wol
White, 1919, AJS, 2d ser., 47(277), 1-59	H_T-H_R	373-1573 K/1 atm	Wol
Hemingway & Robie, 1977, USGS J. Res., 5, 413-429	S	298.15 K/1 atm	Wol
Barany, 1966, US Bur. Mines Rpt. Inv. 6784, 8 p	H	346.85 K/1 atm	Wol=Qza+Lme
Charlu & others, 1978, Geochim. Cosmo. Acta, 42, 367-375	H	970 K/1 atm	Wol=Qzb+Lme
Kracek & others, 1953, Carn. Inst. Wash. Yb., 69-75	H	347.85 K/1 atm	Cwo=Wol
Nacken, 1930, Zement, 19, 818-825 & 847-849	H	314.85 K/1 atm	Cwo=Wol
Benz & Wagner, 1961, J. Phys. Chem., 65, 1308-1311	G(emf)	898-1148 K/1 atm	Wol=Qzb+Lme
Boettcher, 1970, J. Pet., 11, 337-379	G	893-1053 K/3000-5900 bars	Ano+Wol=Gro+Qzb
Gordon & Greenwood, 1971, Am. Min., 56, 1674-1688	G	700-849°C/2000 bars	Ccl+Ano+Wol=Gro+CO_2
Greenwood, 1967, Am. Min., 52, 1669-1680	G	558-595°C/1000-2000 bars	Ccl+Qza=Wol+CO_2
Greenwood, 1967, Am. Min., 52, 1669-1680	G	609-723°C/1000-2000 bars	Ccl+Qzb=Wol+CO_2
Gustafson, 1974, J. Pet., 15, 455-496	G	748-797°C/500-2000 bars	Adr+Fay=Mag+Wol+Qzb
Gustafson, 1974, J. Pet., 15, 455-496	G	789-839°C/500-2000 bars	Adr+Bun=Mag+Wol+Hem
Harker & Tuttle, 1956, AJS, 254, 239-256	G	600-800°C/300-2400 bars	Ccl+Qzb=Wol+CO_2

Haselton & others, 1978, Geophys. Res. Lett., 5, 753-756	G	1000-1325°C/10000-19000 bars	Cc2+Qzb=Wol+CO_2
Hays, 1965, Carn. Inst. Wash. Yb., 234-239	G	1473-1523 K/11000-14600 bars	Gro=Ano+Wol+Geh
Hoschek, 1974, Cont. Min. Pet., 47, 245-254	G	725-825°C/1000-4000 bars	Ano+Wol+Ccl=Gro+CO_2
Hoschek, 1974, Cont. Min. Pet., 47, 245-254	G	755-788°C/1000 bars	Gro+Ccl=Geh+Wol+CO_2
Hoschek, 1974, Cont. Min. Pet., 47, 245-254	G	850-890°C/1000 bars	Ano+Ccl=Geh+Wol+CO_2
Huckenholz, 1974, Carn. Inst. Wash. Yb., 411-426	G	1125-1423 K/200-10000 bars	Gro=Ano+Wol+Geh
Huckenholz, 1974, Carn. Inst. Wash. Yb., 411-426	G	848-858 K/1000-3000 bars	Ano+Wol=Gro+Qza
Huckenholz, 1974, Carn. Inst. Wash. Yb., 411-426	G	888-958 K/4000 bars	Ano+Wol=Gro+Qzb
Liou, 1971, Am. Min., 56, 507-531	G	708-828 K/1974-5527 bars	Ano+Wol+H_2O=Pre
Liou, 1974, Am. Min., 59, 1016-1025	G	570-610°C/500-2000 bars	Adr+Qza+Fay=Hed+Wol
Liou, 1974, Am. Min., 59, 1016-1025	G	621-683°C/500-2000 bars	Adr+Qza+Nic=Hed+Wol+Run
Newton, 1966, AJS, 264, 204-222	G	803-923 K/1100-2000 bars	Ano+Wol=Gro+Qza
Newton, 1966, AJS, 264, 204-222	G	973-1023 K/4700-5700 bars	Ano+Wol=Gro+Qzb
Shmulovich, 1974, Geochem. Int., 11, 883-887	G	1133-1153 K/500-700 atm	Gro=Ano+Wol+Geh
Shmulovich, 1977, Geochem. Int., 14, 126-134	G	627-727°C/1000-3920 bars	Ccl+Wol+Ano=Gro+CO_2
Evans, 1977, pers. comm., 1-5-77	V	25°C/1 atm	Wol
Robie & others, 1967, USGS Bull. 1248, 87 p	V	25°C/1 atm	Wol
Vaidya & others, 1973, JGR, 78, 6893-6898	V	25°C/5000-45000 bars	Wol
Rutstein, 1971, Am. Min., 56, 2040-2052	a	600-1000°C/1000 bars	Wol+Hed($CaSiO_3$-$CaFeSi_2O_6$ soln)

Zoisite $Ca_2Al_3Si_3O_{12}(OH)$ - Epidote group

Important solid solution

(Al,Fe^{+3}) Zoisite - Epidote join

Reference	Data type	Range (Temperature/pressure)	Phases studied
Perkins & others, 1980, Geochim. Cosmo. Acta, 44, 61-84	Cp	200-298 K/1 atm	Zoi
Perkins & others, 1980, Geochim. Cosmo. Acta, 44, 61-84	Cp	298-730 K/1 atm	Zoi
Perkins & others, 1980, Geochim. Cosmo. Acta, 44, 61-84	S	298.15 K	Zoi
Boettcher, 1970, J. Pet., 11, 337-379	G	853-933 K/4000-5300 bars	Gro+Ano+H_2O-Zoi+Qza
Boettcher, 1970, J. Pet., 11, 337-379	G	898-928 K/3000 bars	Gro+Ano+Cor+H_2O-Zoi
Hewitt, D., 1973, Am. Min., 58, 785-791	G	539-540°C/6000 bars	Mus+Ccl+Qza-San+Zoi+CO_2+H_2O
Newton, 1965, J. Geol., 73, 431-441	G	843-1113 K/2000-6800 bars	Gro+Ano+Cor+H_2O-Zoi
Nitsch, 1972, Cont. Min. Pet., 34, 116-134	G	340-385°C/4000-5000 bars	Law=Zoi+Kya+Pyr+H_2O
Nitsch, 1972, Cont. Min. Pet., 34, 116-134	G	370-430°C/7000 bars	Law+Qza-Zoi+Pyr+H_2O
Nitsch, 1974, For. Min., 51, 34-35	G	325-445°C/4000-10000 bars	Law=Zoi+Mar+Qza+H_2O
Storre & Nitsch, 1972, Cont. Min. Pet., 35, 1-10	G	510-700°C/2000-7000 bars	Zoi+CO_2=Ano+Ccl+H_2O
Strens, 1968, Min. Mag., 36, 864-867	G	770-823 K/2000 bars	Gro+Ano+H_2O-Zoi+Qza
Robie & others, 1967, USGS Bull. 1248, 87 p	V	25°C/1 atm	Zoi

Appendix 3. List of abbreviations used for journals

Abbreviated reference	Full reference
AJS	American Journal of Science
Acta Cryst.	Acta Crystallographica
Am. Min.	American Mineralogist
Ann. pour l'an Paris, Bur. longitudes	Annuaire pour l'an (1888) Paris, Bureau des longitudes
Ber. Bunsenges. Physik. Chem.	Berichte der Bunsengesellschaft fur Physikalische Chemie
CODATA Bull.	CODATA Bulletin
Can. Min.	Canadian Mineralogist
Carn. Inst. Wash. Yb.	Carnegie Institute of Washington Yearbook
Cont. 9th Int. Conf. Prop. Steam, Munich	Contributions to the 9th International Conference on the Properties of Steam, Munich, 1979
Cont. Min. Pet.	Contributions to Mineralogy and Petrology
Dokl. Akad. Nauk SSSR	Doklady Akademiia Nauk SSSR
EOS	Transactions of the American Geophysical Union. EOS
Earth Planet. Sci. Lett.	Earth and Planetary Science Letters
Econ. Geol.	Economic Geology
Faraday Soc. Trans.	Journal of the Chemical Society, London, Faraday Transactions
For. Min.	Fortschritte der Mineralogie
GSA Abs. Prog.	Geological Society of America Abstracts with Programs
GSA Bull.	Geological Society of America Bulletin
GSA Mem.	Geological Society of America Memoirs
Geochem. Int.	Geochemistry International
Geochim. Cosmo. Acta	Geochimica et Cosmochimica Acta

Appendix 3. List of abbreviations used for journals

Abbreviated reference	Full reference
Geokhim.	Geokhimiia
Geophys. Res. Lett.	Geophysical Research Letters
Inorg. Chem.	Inorganic Chemistry
Izmer. Tekh.	Izmeritel'naya Tekhnika
J. Am. Ceram. Soc.	Journal of the American Ceramic Society
J. Am. Chem. Soc.	Journal of the American Chemical Society
J. Appl. Phys.	Journal of Applied Physics
J. Chem. Thermodyn.	Journal of Chemical Thermodynamics
J. Chim. Phys.	Journal de Chimie Physique et de Physico-Chimie Biologique
J. Franklin Inst.	Journal of the Franklin Institute
J. Geol.	Journal of Geology
J. Inorg. Nuc. Chem.	Journal of Inorganic and Nuclear Chemistry
J. Pet.	Journal of Petrology
J. Phys. Chem. Ref. Data	Journal of Physical and Chemical Reference Data
J. Phys. Chem. Solids	Journal of Physics and Chemistry of Solids
J. Phys. Chem.	Journal of Physical Chemistry
J. Sed. Pet.	Journal of Sedimentary Petrology
JANAF	JANAF, National Standard Reference Data Series
JGR	Journal of Geophysical Research
Japan. J. Geol. Geog.	Japanese Journal of Geology and Geography
Kristall.	Kristallografiia
Lithos	Lithos

Appendix 3. List of abbreviations used for journals

Abbreviated reference	Full reference
Meas. Tech.	Measurement Techniques
Mem. Sci. Rev. Metal.	Memoires Scientifiques de la Revue de Metallurgie
Min. Mag.	Mineralogical Magazine
Moscow Univ. Geol. Bull.	Moscow University Geology Bulletin
Nature	Nature
Naturw.	Naturwissenschaften
Neorg. Mater.	Izvestiia Akademii Nauk SSSR, Neorganicheskie Materialy
Neues Jahrb. Min., A.	Neues Jahrbuch fur Mineralogie, Abhandlungen
Neues Jahrb. Min., M.	Neues Jahrbuch fur Mineralogie, Monatshefte
Ocherki Fiz.-Khim. Pet.	Ocherki Fiziko-Khimicheskoi Petrologii
Pers. comm.	Personal communication
Phys. Chem. Glass	Physics and Chemistry of Glasses
Phys. Earth Planet. Int.	Physics of the Earth and Planetary Interiors
Phys. Soc. London Proc.	Proceedings of the Physical Society, London
Proc. Geol. Soc. China	Proceedings of the Geological Society of China
Proc. Imp. Acad. Japan	Proceedings of the Imperial Academy (Tokyo)
Proc. Indian Acad. Sci.	Proceedings - Indian Academy of Sciences
Proc. NATO Adv. Study Inst.	Proceedings of the NATO Advanced Study Institute Series
Proc. Nat. Acad. Sci.	Proceedings of the National Academy of Sciences (U.S.)
Proc. Roy. Soc. Lond.	Proceedings of the Royal Society of London
Prog. Astronau. Aeronau.	Progress in Astronautics and Aeronautics
Prog. Exp. Pet.	Progress in Experimental Petrology
Res. Geochem.	Researches in Geochemistry

Appendix 3. List of abbreviations used for journals

Abbreviated reference	Full reference
Rpt. Brit. Admir.	Report to the British Admiralty
Russ. J. Inorg. Chem.	Russian Journal of Inorganic Chemistry
Schweiz. Min. Petrogr. Mitt.	Schweizerische Mineralogische und Petrographische Mitteilungen
Sci.	Science
The Feldspars, NATO Adv. Study Inst.	The Feldspars, NATO Advanced Study Institute Series
Thermo. in Geol.	Thermodynamics in Geology
Trans. Brit. Ceram. Soc.	Transactions of the British Ceramic Society
Trans. Metal. Soc. AIME	Transactions of the Metallurgical Society of AIME
Tsch. Min. Pet. Mitt.	Tschermaks Mineralogische und Petrographische Mitteilungen
US Bur. Mines Bull.	U.S. Bureau of Mines Bulletin
US Bur. Mines Rpt. Inv.	U.S. Bureau of Mines Report of Investigations
US NBS Circ.	U.S. National Bureau of Standards Circular
US NBS Interim Rpt.	U.S. National Bureau of Standards Interim Report
US NBS NSRDS-NBS	U.S. National Bureau of Standards, National Standard Reference Data Series
US NBS Tech. Note	U.S. National Bureau of Standards Technical Note
USGS Bull.	U.S. Geological Survey Bulletin
USGS J. Res.	U.S. Geological Survey Journal of Research
USGS Prof. Paper	U.S. Geological Survey Professional Paper
Wash. Acad. Sci. J.	Journal of the Washington Academy of Sciences
Z. Anorg. Allg. Chem.	Zeitschrift fur Anorganische und Allgemeine Chemie
Z. Anorg. Chem.	Zeitschrift fur Anorganische Chemie
Z. Electrochem.	Zeitschrift fur Elektrochemie
Z. Elek. Angew. Phys. Chem.	Zeitschrift fur Elektrochemie und Angewandte Physikalische Chemie
Z. Krist.	Zeitschrift fur Kristallographie
Z. Phys. Chem.	Zeitschrift fur Physikalische Chemie
Zement	Zement