Experimentally determined melting relations in simple and complex chemical systems at pressures up to 23 GPa

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Introduction and methods

The 10 mm sample assembly designed by Gasparik (1989) for use in the split-sphere anvil apparatus or similar high-pressure devices allows to carry out routine experiments in the full pressure range of the Earth's upper mantle, and at the temperatures reaching 2800°C. Numerous melting curves have been experimentally determined with this assembly using the split- sphere anvil apparatus (USSA-2000) in the Stony Brook High Pressure Laboratory. The experiments were carried out with the same assembly, press, experimental procedures, and calibrations, to maximize the internal consistency of the results. Thus, the relative position of the melting curves is likely to be known within 10–30°C, although a systematic error in all melting temperatures could be caused by an unknown effect of pressure on the emf of the W3Re/W25Re thermocouple. This error is likely to be very small because of an excellent agreement between our estimate of the melting temperature of $MgSiO_3$ perovskite (2600°C at 22.5 GPa, Gasparik 1990) and the melting temperatures obtained by Zerr and Boehler (1993) in a diamond cell. Melting curves determined recently in other laboratories are often in close agreement with our results, thus indicating the absence of a potential bias caused by our experimental techniques.

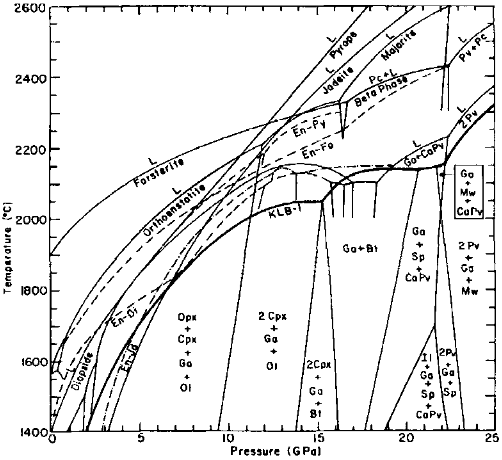

FIG. 1. Temperature-pressure phase diagram showing melting curves of simple compounds and solidi in more complex chemical systems. The subsolidus assemblages apply to KLB-1.

Results

The melting curves in anhydrous systems are summarized in Fig. 1, and the corresponding equations are listed in Table 1. For simple compounds, these include the melting curves of enstatite at 10–16.5 GPa (Presnall and Gasparik, 1990), diopside at 8–17 GPa (Gasparik, 1994), jadeite at 2.5–16.5 GPa (Litvin and Gasparik, 1993) and pyrope at 7–16 GPa (Zhang and Herzberg, 1994a). Melting of forsterite was reported by Presnall and Gasparik (1990) at 16.5 GPa. This result agrees with the melting curve determined by Presnall and Walter (1993) at 9.7–16.5 GPa using our assembly and procedures, but a different press. Not shown is the melting of SiO_2 at 9–14 GPa by Zhang *et al.* (1993).

Solidi in simple binary systems were determined for the enstatite-pyrope join at 8–15.2 GPa (Gasparik, 1992a), enstatite- diopside join at 7–22.4 GPa (Gasparik, 1994), and enstatite-jadeite join at 9-15.2 GPa (Gasparik, 1992b). The eutectic on the enstatite-forsterite join was located at 16.5 GPa and 2250°C (Presnall and Gasparik, 1990) and at 22.4 GPa and 2430°C (Gasparik, 1990). Complex chemical systems are represented by the solidus for the KLB-1 natural peridotite determined by Zhang and Herzberg (1994b) at 5–22.4 GPa.

In volatile-bearing systems, the melting curve of brucite was determined by Gasparik and Zhang (1992) at 6–22 GPa, and the solidi in the system MgO-SiO_2 with low volatile contents of H_2O, F_2 and Cl_2 were determined by Gasparik (1993) at 10–23 GPa.

TABLE 1. Equations for selected melting curves

Melting curve	Equation (GPa, K)	Range (GPa)
Ortho enstatite	$P = 1.9[(T/1840)^{6.6} - 1]$	0–12
Diopside	$P = 1.75[(T/1665)^{5.6} - 1]$	0–11
Jadeite	$P = 2.5 + 2.01[(T/1543)^{3.7} - 1]$	2.5–17
Forsterite	$P = 2.44[(T/2171)^{11.4} - 1]$	0–17
Pyrope	$P = (T - 1828)/58.4$	5–16

Applications

These recently obtained data place important constraints on the processes which resulted in the present mineral and chemical composition of the Earth's upper mantle. The results from anhydrous systems are applicable to the crystallization and potential fractionation in a magma ocean, and to the origin of komatiites and peridotites. Melting in volatile-bearing systems is relevant to plate tectonics, mantle dynamics, and the origin of asthenosphere. The results support a mineralogically and chemically stratified upper mantle, and a homogeneous, partially molten lower mantle, where convection occurs due to the presence of an interstitial volatile-bearing melt despite the low homologous temperatures with respect to the anhydrous melting.

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