Igneous & Metamorphic Petrology Exercise
Calculated Phase Boundaries

Calculation of Crystal-Melt Phase Boundaries

The purpose of this exercise is to demonstrate how thermodynamic data derived from experiments can be used to construct phase diagrams of crystal-melt equilibrium. In this example we will use thermodynamic data for the anorthite (An) and diopside (Di) mineral phases to construct a phase diagram useful for interpreting the crystallization of basaltic magma.

Given the melting point temperature (MP) of a pure mineral phase, and the enthalpy of melting (ΔH_{MELT}) of a pure phase, and assuming that it reacts with other mineral phases in an ideal chemical manner:

$$\ln X = \frac{\Delta H_{MELT}}{R}\left[\frac{1}{MP} - \frac{1}{T}\right] \qquad \textbf{(1)}$$

Where X is the proportion of the component in the system, R is the constant 8.31 J/°K•mole, and T is the temperature of the crystal-melt phase boundary in degrees kelvin. For this exercise we would like to rearrange the equation so as to solve for T at a specified X value:

$$T = \frac{1}{\dfrac{1}{MP} - \dfrac{\ln X(R)}{\Delta H_{MELT}}} \qquad \textbf{(2)}$$

As you can determine from equations **(1)** and **(2)**, if a mineral phase is pure, X = 1.0, and therefore T would equal the melting point (MP) of the pure phase. As the mineral phase is diluted by other chemical components in the system, the denominator of equation **(2)** must become larger, forcing T to become a smaller value. This effect is termed the freezing point depression by chemists, but is also well known to experimental petrologists. The depression of melting point will occur in any phase when it is diluted by other chemical components.

To complete the exercise you need to make two tables which calculate the temperature of the crystal-melt phase boundary for An and Di at values of X(An) equal to 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, and 0.9. You should use the table provided at the end of this document to tabulate the calculated temperatures for the two curves. Note that the function ln(0.0) is undefined, therefore, you cannot calculate the curve at X = 0.0. When the temperature values are tabulated, the two curves for An+melt and Di+melt should be plotted on a graph of T°C versus X(An). Use Figure 1 to construct your graph. Make sure that you convert temperatures from kelvin to centigrade (°K = 273 + °C) when plotting the two curves. Where these two curves meet defines the temperature of the solidus which you should also draw on Figure 1. Both of the liquidus curves should terminate at the solidus; do not extend them below the solidus. After all phase boundaries are sketched onto Figure 1, label all fields on the diagram with the phases that occur within the fields (An+Di, An+melt, etc.). You will need the following thermodynamic data to

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construct the diagram:

	Anorthite (An)	Diopside (Di)
Melting Point °K	1830.0	1664.0
Enthalpy (ΔH_{MELT}) of melting in joules	81000.0	77404.0

Table for Plotting Liquidus Curves

X_{An}	T °C (An+melt)	X_{Di}	T °C (Di+Melt)
0.9		0.9	
0.8		0.8	
0.7		0.7	
0.6		0.6	
0.5		0.5	
0.4		0.4	
0.3		0.3	
0.2		0.2	
0.1		0.1	

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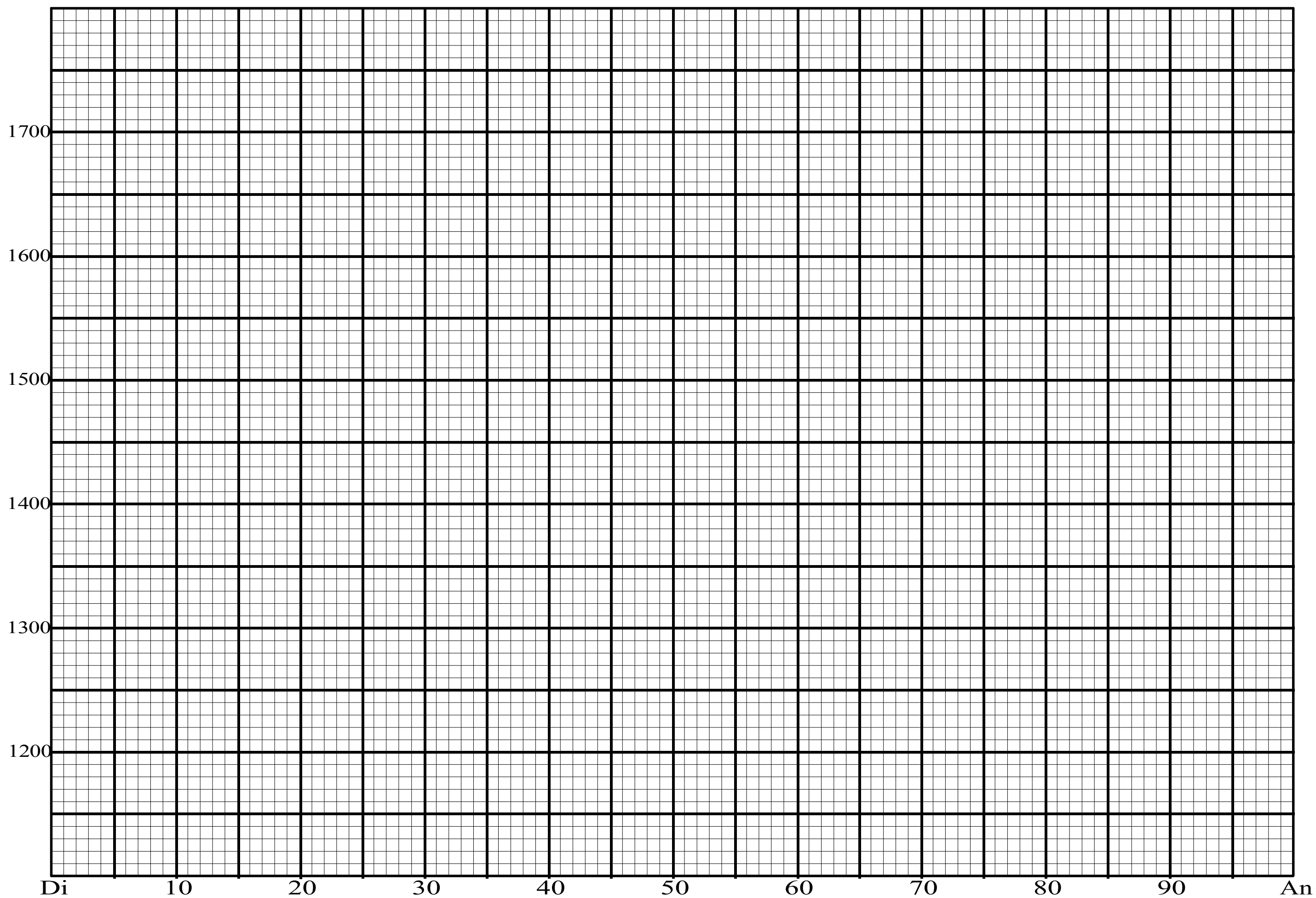

Figure 1. Graph for constructing the X(An) vs. T°C phase diagram.