12.480 Handout #3

Reading

Stormer (1975) Am. Mineral 60, 667-674.
Whitney and Stormer (1977) Am. Mineral 62, 687-691.
Andersen and Lindsley (1981) GCA 45, 847-853.

Supplementary Reading

Griffen, Dana T. *Silicate Crystal Chemistry*, Chapter 2. New York, NY: Oxford University Press, 1992. ISBN: 0195044423
Ribbe, P. H. (ed.) *Feldspar Mineralogy (Reviews in Mineralogy, Vol. 2, 2nd ed.)*. Washington, D. C.: Mineralogical Society of America, 1983. ISBN: 0939950146

Two feldspar themometry-barometry

The use of coexisting plagioclase and alkali feldspars to predict temperature and pressure of equilibration was first proposed by Barth (1951) who used natural phase assemblages to calibrate a thermometer. Stormer and Whitney and Stormer subsequently develop a simple thermodynamic model for treating feldspar equilibria. The important assumptions for this model were:

1. Use one of the conditions of equilibrium.

   $$\mu_{Ab}^{AF} = \mu_{Ab}^{PF}$$

   where AF = alkali feldspar and PF = plagioclase feldspar.

2. Assume that Or content in PF has no effect on a_{Ab}^{PF} and that An content in AF has no effect on a_{Ab}^{AF}.
   The equilibrium condition can be written

   $$\mu_{Ab}^{AF} = \mu_{Ab}^{oAF} + RT \ln_{aAb}^{AF}$$

   $$\mu_{Ab}^{PF} = \mu_{Ab}^{oPF} + RT \ln_{aAb}^{PF}$$

3. Assume that the standard state chemical potential for pure Ab in both phases was the same. Then

   $$0 = RT \ln \frac{a_{Ab}^{AF}}{a_{Ab}^{PF}}$$

   $$= RT \ln \frac{\gamma_{Ab}^{AF} X_{Ab}^{AF}}{\gamma_{Ab}^{PF} X_{Ab}^{PF}}$$

4. Assume $\gamma_{Ab}^{PF} = 1$, so

   $$\ln \frac{X_{Ab}^{AF}}{X_{Ab}^{PF}} = \ln \gamma_{Ab}^{AF}$$

   $$\ln \gamma_{Ab}^{AF} = \frac{1}{RT} \left(2W_{GOr} - W_{GAb}\right) (X_{Or}^{AF})^2 + 2 \left(W_{GAb} - W_{GOr}\right) (X_{Or}^{AF})^3$$

   Several of the simplifications of the Whitney and Stormer thermometer have been dealt with in subsequent models of feldspar equilibria, and some have not.

First Assumption

The μ^o's are not equal and we require two sets of W's! So

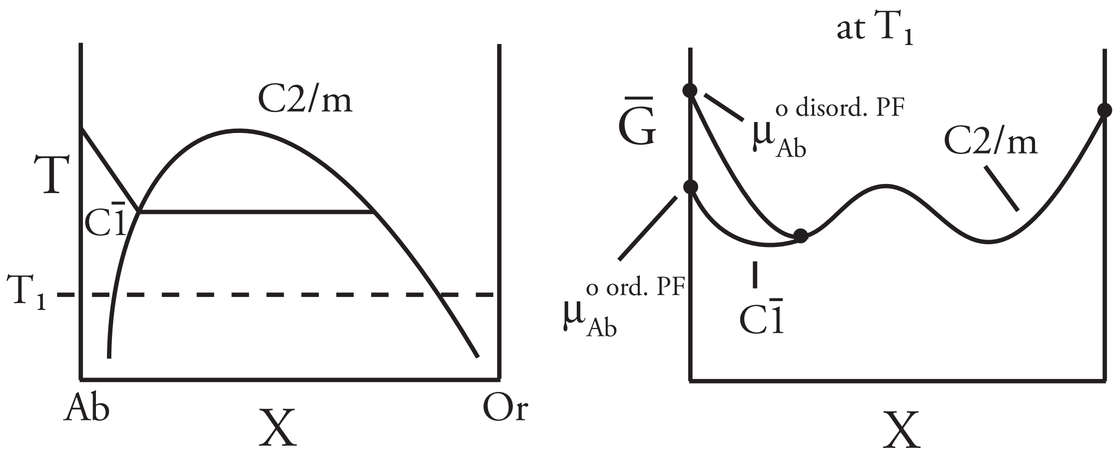
$$\mu_{Ab}^{AF} = \mu_{Ab}^{PF}$$

$$\mu_{Ab}^{AF} = \mu_{Ab}^{o\,\text{disord}AF} + RT\ln\gamma_{Ab}X_{Ab}$$

where W's were appropriate to disordered 0.

$$\mu_{Ab}^{PF} = \mu_{AB}^{o\,\text{ordered plag}} + RT\ln\gamma_{Ab}X_{Ab}$$

potentially we also need W's for a different solution.



Second Assumption

A ternary solution model would be more appropriate.

$$\begin{aligned} RT\ln\gamma_1 = {} & W_{G12}X_1^2X_2 + W_{G21}X_2^2X_1 \\ & + W_{G13}X_1^2X_3 + W_{G31}X_3^2X_1 \\ & + W_{G23}X_2^2X_3 + W_{G32}X_3^2X_2 \end{aligned}$$

Margules formulations for ternary and quaternary solutions were developed by Wohl (1946, 1953).

Lindsley and Anderson (1981) go through the exercise of deriving an expression for a ternary asymmetric model. These models, like the ones for binary systems, assume that a polynomial of degree 2 (symmetric) or degree 3 (asymmetric) in component 2 and 3 are adequate models of the excess free energy of mixing.