Three Component System and Reactions

C:\Courses\320\in-class\06-description.wpd; August 23, 2003 (11:20am)

The diagrams on the accompanying page show the three component system CaO-Al_2O_3-SiO_2 and the phases (minerals):

grossular	$Ca_3Al_2Si_3O_{12}$
quartz	SiO_2
kyanite	Al_2SiO_5
wollastonite	$CaSiO_3$
anorthite	$Ca_3Al_2Si_3O_{12}$

Note that we could choose an alternative set of components (bottom triangle) but we generally use oxide components when possible because it is simplest.

The phase rule says that

$C + 2 = P + F$

In this case, C = 3, so

$P + F = 5$

For a univariant reaction, F= 1, so

$P = 4$ (This means there are four phases in univariant reactions.)

Two examples of univariant (F=1) reactions are shown on triangles on the next page:

$3An = Gr + Ky + 2Q$

$Gr + Q = An + 2Wo$

Also listed on the next page is one degenerate reaction (An=Ky+Wo). Degenerate reactions are reactions that involve one less component (and phase) than the system we are modelling. The reaction An=Ky+Wo really only involves two components (Ky and Wo) which can be seen because all three minerals plot on a line.

Note that there are three types of reactions involving the phases being considered. (crossing tie lines, triangle, and degenerate - see next page). Note where the different phases plot on the triangular diagram and how that relates to the kind of reaction.

Crossing tie line reactions have two phases on each side, e.g.:

$Gr + Q = An + Wo$

Triangle reactions have one phase on one side and three on the other:

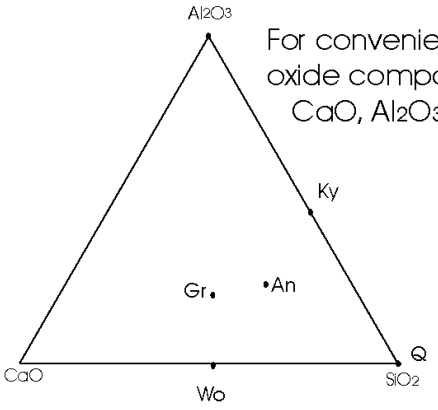
$3An = Gr + Ky + 2Q$

Degenerate reactions have one fewer phase, e.g.: An=Ky+Wo

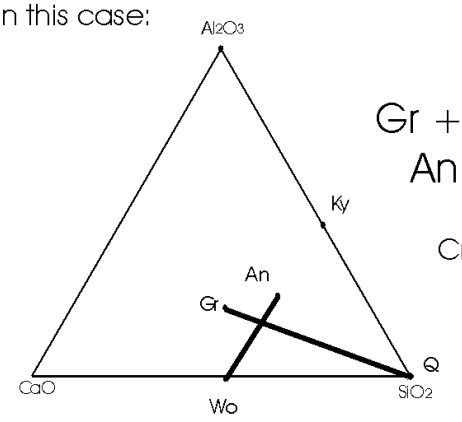
.

Three Components System and Reactions

Grossular ($Ca_3Al_2Si_3O_{12}$), Quartz (SiO_2), Anorthite ($CaAl_2Si_2O_8$), Wollastonite ($CaSiO_3$), Kyanite (Al_2SiO_5)

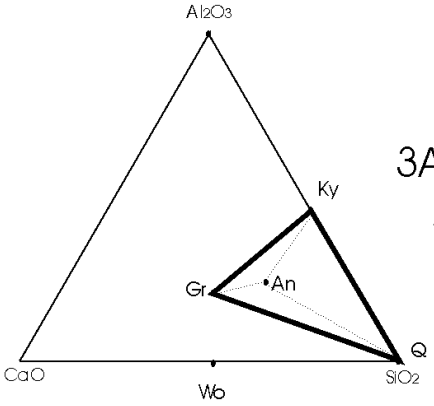


For convenience we often use oxide components. In this case:
CaO, Al_2O_3, SiO_2



$Gr + Q = An + 2\,Wo$

Crossing tie line reaction

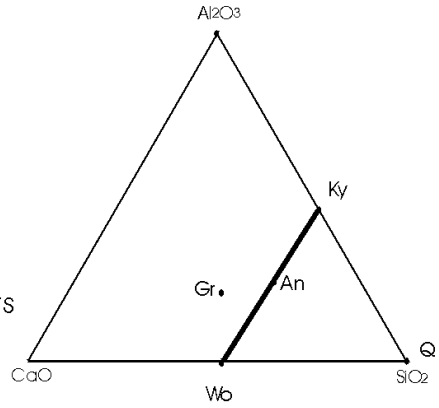


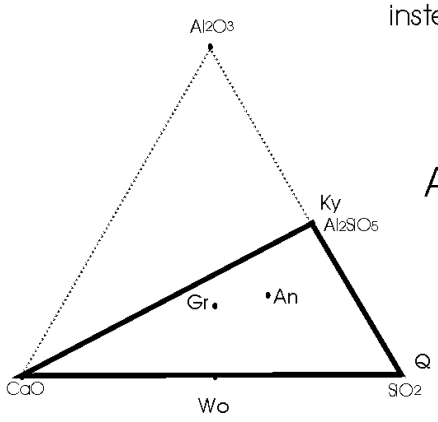
$3An = Gr + 2Ky + Q$

Triangle reaction

$An = Ky + Wo$

Degenerate reaction
(involves only two components instead of three)





Alternative components

We could have chosen the components:
Al_2SiO_5, SiO_2, CaO
But why bother and make things complicated?

What other reaction or reactions can take place in the CaO-Al_2O_3-SiO_2 system, considering only the phases grossular, quartz, kyanite, wollastonite, anorthite?

To answer this, note that we are considering a 3 component system. So, every reaction will involve 4 phases. (Unless it is degenerate – then it will involve fewer.) The easiest way to count reactions is often to think about the phases missing from each reaction. By convention, we put missing phases in parentheses (table below). We are considering the phases An, Gr, Ky, Q, Wo. So far we have three reactions, and the fourth one must be missing An:

#	missing phase	reaction
1	(Wo)	3An = Gr + Ky + 2 Q
2	(Ky)	Gr + Q = An + 2Wo
3	(Gr, Q) (degenerate)	An = Ky + Wo
4	(An)	???

What is Reaction #4? You can figure this out by algebraically adding or subtracting the reactions you already know about. For example, add reaction #2 and reaction #3:

Gr + Q = An + 2Wo
An = Ky + Wo
Gr + Q = Ky + 3Wo (= reaction #4)

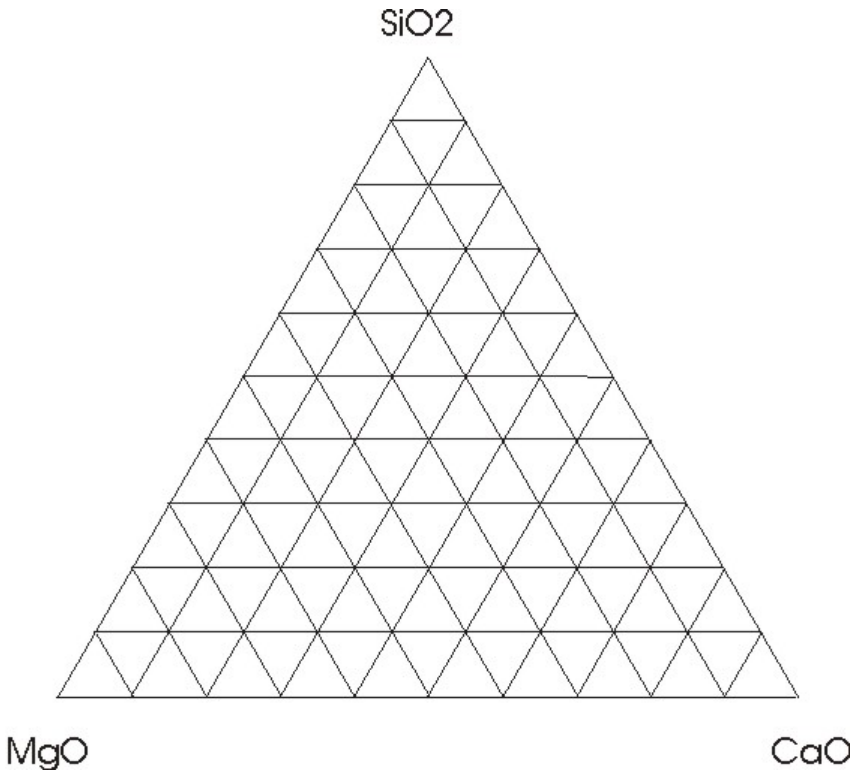
An alternative way to determine this reaction is to note that the four phases plot to produce a crossing tie line configuration. So, you know that Gr+Q is on one side and Ky+ Wo is on the other. Then you can experiment with different reaction coefficients until you figure out that 3Wo is needed to make it balance.

Problem

Consider the minerals periclase, forsterite, quartz, diopside, akermanite and wollastonite:

periclase	Pe	MgO
forsterite	Fo	Mg_2SiO_4
quartz	Q	SiO_2
diopside	Di	$CaMgSi_2O_6$
akermanite	Ak	$Ca_2MgSi_2O_7$
wollastonite	Wo	$CaSiO_3$

Plot the 6 phases on the triangular diagram below. Then make a complete list of reactions that involves these phases. Be sure to balance the reactions.



Hint: We have 3 components but 6 phases. Every reaction can contain 4 phases and so must be missing 2. For example, one reaction will be missing (Q,Wo), and another will be missing (Di,Fo). These two reactions are:

3Pe + 2Di = 2Fo + Ak

Ak = 2Wo + Pe (degenerate)

You figure out the rest!