12.109 Lecture Notes
October 4, 2005

Oxygen Barometers (see handout from last week)

(discussion of hand samples in class, xenoliths from the mantle in basalt. Xenolith = foreign rock)

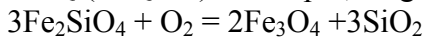Important variables in earth and planets:
T
P
Volatile-gases-fluids
$O_2 - Fe - FeO - Fe_2O_3$ (also S)
H_2O
CO_2

Oxygen buffers
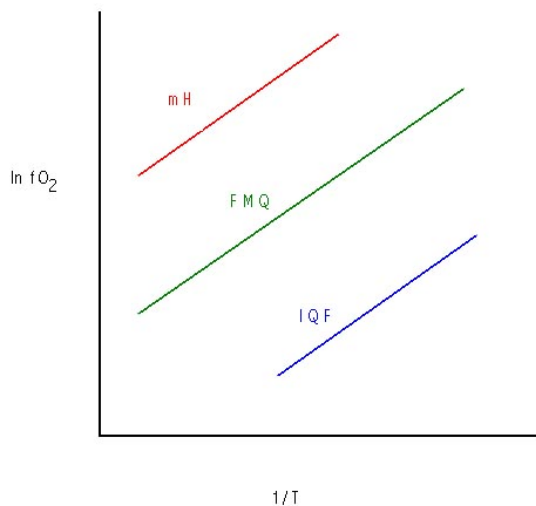FMQ (or QFM) – feldspar, magnetite, quartz
$3Fe_2SiO_4 + O_2 = 2Fe_3O_4 + 3SiO_2$
Controlled by f_{O2}, oxygen fugacity (tendency to escape)
$f_{O2} = \gamma$, correction for non-ideal behavior

Oxygen buffers are nice because the minerals for the reaction can be found as pure phases. If a phase is pure, a = 1.

$$k_{eq} = \frac{(a_{Fe_3O_4}^{mag})^2 (a_{SiO_2}^{qtz})^3}{(a_{Fe_2SiO_4}^{oliv})^3 (f_{O_2})} = \frac{1}{f_{O_2}}$$

$$\ln f_{O_2} = \frac{\Delta G_{rxn}}{RT}$$

Two coexisting minerals that are the most common oxybarometers:
Ulvospinel-magnetite
Hematite-ilmenite
With these you can solve for both T + P!

<u>Samples of the deep earth</u>
The accessible ones are not very deep—most are from <100 km. In some rare cases, the pieces of the cratonic mantle from up to 250 km depth are preserved.
Mineral inclusions in diamonds are mostly "regular" ultramafic minerals, but sometimes we find $CaSiO_3$, $MgSiO_3$ – perovskite?
We have determined by laboratory experiments that with T and P found @ 670 km, ringwoodite (a spinel, found in meteorites) transitions to Mg-perovskite and MgO periclase. We have no samples from the lower mantle, however.

Mantle rocks are usually peridotite (see rock naming handout).
Harzburgites have been chemically depleted by melting and melt extraction.

Al-bearing minerals present in rocks tell about depth of equilibration.
Shallow   plag peridotite
| spinel peridotite
Deeper   garnet peridotite (mostly pyrope)

Cratons – pieces of thick mantle lithosphere found under ancient crustal rocks. Interestingly, they are old (>3 billion years). There is extremely low heat flow in a craton. The lithospheric root of the craton is 250-300 km deep, compared to 100 km deep under average lithosphere.

How do cratons form? This is one of the outstanding problems in geology. One possibility is that cratons formed above subduction zones in the Archean, 3.5 billion years ago. Supporting evidence is the existence of komatiites in cratons.