Ge 101 Problem Set 3
Due Wednesday Nov. 21, 2012

1. **How extinct is extinct?**
The half-life of ^{26}Al is 7.1 x 10^5 years. The initial solar system ratio of ^{26}Al/Al at 4.56 x 10^9 years ago when primitive meteorite inclusions crystallized was 5 x 10^{-5}. The solar abundance of Al by weight is 0.86%, and the mass of the solar system is ~4 x 10^{30} kg.
    (a) Calculate the number of atoms of ^{26}Al in the solar system 4.56 x 10^9 years ago.
    (b) Calculate the number of atoms of ^{26}Al in the solar system today.

2. **Isotope geochemistry gets practical**
In April of 1986 the fallout of the Chernobyl reactor accident was monitored at Studsvik, Sweden, by L. Devell and colleagues (Nature, 1986, v.321, p.192). ^{131}I ($\lambda_{131} = 0.086$ day^{-1}) and ^{133}I ($\lambda_{133} = 0.800$ day^{-1}) were among the radioactive isotopes identified in the fallout. The table below lists the ratio of concentrations of ^{133}I relative to ^{131}I that were measured at noon GMT on the given date:

Date	^{133}I/^{131}I
April 28	0.25
April 29	0.123
April 30	0.0603
May 1	0.0295
May 2	0.0145

The type of nuclear reactor used at Chernobyl is known to produce iodine with a ratio ^{133}I/^{131}I = 2.14. Determine the date and time (GMT) that the reactor explosion occurred. These data were the first clue to the outside world that the world's most serious commercial nuclear accident (up to that time – we'll know someday whether Fukushima Daiichi is worse) had occurred, and they give the correct time for the incident with just a small error.

3. **Rb/Sr isochron**s

	$\left(\dfrac{^{87}Rb}{^{86}Sr}\right)$	$\left(\dfrac{^{87}Sr}{^{86}Sr}\right)$	$\left(\dfrac{^{87}Sr}{^{86}Sr}\right)_{initial}$
Bulk Earth	0.0827	0.7045	0.69898
Whole Rock A	0.1000	0.7245	
Whole Rock B	0.4000	0.7381	
Biotite from Rock B	0.5000	0.7394	
Plagioclase from Rock B	0.0100	0.7321	

    $\lambda_{Rb} = 1.42$ x 10^{-11} yr.$^{-1}$

The table above lists the isotopic compositions of the Bulk Earth, two coexisting igneous rocks and two minerals separated from Rock B. We presume that Rock A and Rock B formed at the same time from the same initial Sr reservoir.

(a) Plot the data in a $\left(\dfrac{^{87}Sr}{^{86}Sr}\right)$ vs. $\left(\dfrac{^{87}Rb}{^{86}Sr}\right)$ (by 'vs.' I mean y vs. x) diagram. Include the

    Bulk Earth isochron, the whole rock isochron defined by the two Rocks, and the mineral isochron from Rock B.

(b) Obtain the ages of isochrons defined by the Bulk Earth, by the pair of whole rocks, and by the mineral separates. Also obtain the initial ($^{87}Sr/^{86}Sr$) ratio for the whole rock isochron and the mineral separate isochron.

(c) Why do you suppose the minerals from rock B give a different age (older or younger?) than the age based on the whole rock, and what might each of the two ages mean? Summarize what can be known about the history of this rock suite.

4. Trace elements and accumulated fractional melting

(a) For a trace element with constant D, in lecture we derived (rather abruptly) the expression for the composition of each increment of instantaneous liquid produced during fractional melting:

$$C_i^m = \frac{C_i^o}{D}(1-F)^{(\frac{1}{D}-1)}$$

Derive the expression for the composition of the *accumulated fractional liquid*, i.e. the average composition of all increments of liquid extracted from the beginning of melting up to F.

(b) For an element with a constant bulk D of 0.05, plot the concentration relative to source C_i^m / C_i^o as a function of F from 0 to 1 for batch melts, instantaneous fractional melts, and integrated fractional melts (this might be a good opportunity to use a computer). Describe the differences between the three curves.

(c) Now plot the concentration relative to source of the solid residues for batch melting and fractional melting (note: the solid residue does not know whether you are integrating the fractional melts somewhere; it is always in equilibrium with the instantaneous melt). If the reasonable choices for how a given magma was produced are batch melting or integrated fractional melting and you have samples of the erupted liquid and some residual xenoliths and a machine for analyzing the concentration of this element with D=0.05, should you analyze the liquid or the residues to identify the melting process? Why might this be difficult if the extent of melting were large?

5. **Core formation and mantle composition**
a. The simplest model for the composition of the mantle left after core formation would assume complete equilibrium between the mantle and core and is therefore governed by the batch melting equation. Assume that the earth begins with chondritic abundances of Ir, Re, Mo, and Ag. Calculate the concentrations relative to chondritic in the mantle after equilibrium core formation. Use the following data:

Mass of core	1.936×10^{24} kg
Mass of mantle	4.016×10^{24} kg
Silicate/Metal partition coefficients:	
Ir	.00005
Re	.0005
Mo	.0008
Ag	.01

b. Look at the figure on Slide 4 of the Lecture 11 notes. Does this model do a good job predicting the relative abundances of the siderophile elements in the mantle?

c. Now try mixing 1% CI chondrite material into the mantle composition from part (a). Is that better? This is the basis of ideas referred to as the "late veneer" or "heterogeneous accretion".