12.007 Geobiology
Spring 2009

12.007 Problem Set 1

Due 2/12/09

1. Why is Fe such a strong peak in the cosmic abundance? Why are elements with atomic number greater than 92 not found in nature? Might they once have existed? Why/why not?

2. Imagine that you are a fossil hunter looking for trilobites. Which information about the geology of different regions would you request before you make your travel plans? Would you expect to find trilobites in Hawaii? Why/why not? Where would you go (anywhere in the world) if you were a meteorite hunter and why?

3. U/Pb: The age of meteorites and the Earth

The first geochronologic determinations of the age of the Earth and the Solar System were based on the U/Pb decay series:

$^{235}U \rightarrow {}^{207}Pb \quad \lambda_1=9.72 \times 10^{-10}\ yr^{-1}$

$^{238}U \rightarrow {}^{206}Pb \quad \lambda_2=1.54 \times 10^{-10}\ yr^{-1}$

The following data are excerpted from Patterson's classic paper "Age of Meteorites and the Earth" (GCA, 10: 230-237):

Sample	**$^{206}Pb/^{204}Pb$**	**$^{207}Pb/^{204}Pb$**
Nuevo Laedo, Mexico	50.28	34.86
Forest City, Iowa	19.27	15.95
Modoc, Kansas	19.48	15.76
Henbury, Australia	9.55	10.38
Canyon Diablo, Arizona	9.46	10.34
Ocean Sediment	19.0	15.8

[Note that meteorites are often named after the location where they fall]

A) The data from the Canyon Diablo meteorite were collected by measuring the Pb isotopic composition in the mineral troilite. What is the chemical formula of this mineral? Where is troilite commonly found?

B) Starting with the rate expressions for radioactive decay of ^{238}U and ^{235}U above, derive the equation:

where R_1= $^{207}Pb/^{204}Pb$, R_2= $^{206}Pb/^{204}Pb$ and k = $^{238}U/^{235}U$ today. Why is this form of equation unique to the U/Pb system? What made this equation useful in the early days of geochronology? Use $(^{238}U/^{235}U)_{today}$ = 137.8

C) On a diagram of $^{207}Pb/^{204}Pb$ vs. $^{206}Pb/^{204}Pb$, plot the isochrons for samples that are 1, 2, 3, 4 and 5 billion years old. Assume that the initial Pb isotopic composition is the same as that measured in the Canyon Diablo meteorite (table). Why is this a valid assumption? Plot the other meteorite data on this figure, as well as the data for oceanic sediment. Explain why these data plot along a line, instead of plotting at one point. Canyon Diablo has $^{238}U/^{204}Pb$= 0.025

D) Based on part D, what is the age of the Solar System? What is the age of the Earth? You may need to solve this graphically. List the assumptions that you made while making the age calculations.

4. 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(λ=0.086/day) and ^{133}I ((λ=0.800/day) were among the radioactive isotopes identified in the fallout. The table below lists the ratio of concentrations of ^{133}I relative to ^{131}I which would have been measured at noon on the given date.

Date	**Concentration of ^{133}I relative to ^{131}I**
April 28	0.25
April 29	0.123
April 30	0.0603
May 1	0.0295
May 2	0.0145

The nuclear reactions in the Chernobyl reactor produce $^{133}I/^{131}I$=2.14. Determine the date and time when the explosion occurred. These data were the first clue to the outside world that the world's most serious commercial nuclear accident had occurred and they give the correct time for the incident with just a small error.

5. If someone told you that British Columbia was close to Baja California before 85 million years ago, how would you test this hypothesis? How would you explain the migration of these rocks?