EOS 240: Lab Assignment 5

Sm-Nd Decay

Due: 2:30 pm March 07, 2024 (Th section)
Due: 1:30 pm March 08, 2024 (F section)

You have one week to complete this assignment. You should submit your response to the course Brightspace page as a single PDF file. **Additionally, we ask that you upload a copy of the scripts, code, or spreadsheets you used to complete the assignment. These documents will help us track down mistakes.** Responses to questions should be typed, using complete sentences and standard grammar. If you choose to support your answers with hand-drawn illustrations or hand-written calculations, you should scan or photograph the written work and integrate it into your PDF file as a figure. Double check that your image resolution is high enough to read. A google search of 'PDF combiner' will return a number of webpages that allow you to upload individual images and combine them into a single .pdf file (example: combinepdf.com). There are also a number of good apps for mobile phones. If you write your response in a word processor, please export to .PDF before submitting your response.

You are not excluded from working with others (pairs are recommended), but each person will submit their own copy of the assignment. In your submission, include the names of anyone you worked with on the assignment.

To answer the questions, you can perform calculations and make figures using Excel (an open source alternative: www.libreoffice.com), or with a program or programming language of choice.

Name : ______________________________

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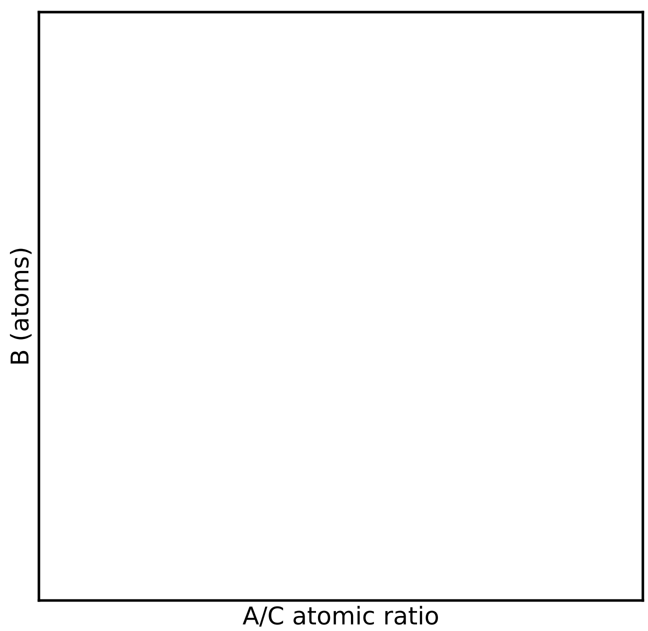
Marks:	5	3	11	19
Score:				

Question 1 (19)

SM-ND DECAY

(a) (4 points) Basalts form from the melting of peridotite. Consider the case where a series of basalts are extracted from a massive, well mixed, mantle source rock. Each individual basalt has a distinct melt fraction, F. You are interested in three elements in the basalt, which we will call element **A**, **B**, and **C**. Elements **A** and **C** are incompatible and have the same bulk partition coefficients. Element **B** is infinitely compatible. Additionally, element **A** decays to element **B** at a geologically observable decay rate (element **C** is stable). Discuss with your peers and draw the following features on the blank schematic figure below:

- (2 points) The initial composition of at least two basalts with different melt fractions (assume the source is unchanging)
- (2 points) The evolution of each sample over time



(b) (1 point) ^{147}Sm decays to ^{143}Nd through alpha decay with a decay constant of λ^{147}=6.54E–12. Write the equation describing how ^{143}Nd changes over time (use λ^{147}, ^{147}Sm, and ^{143}Nd$_{\text{initial}}$ and normalize to ^{144}Nd).

(c) (1 point) Rearrange your equation from (b) to solve for initial ^{143}Nd/^{144}Nd. With this equation you can calculate how the child isotope has evolved over time. Typically, we assume that the primitive mantle of Earth has the same isotopic composition of chondrites. We call this the Chondritic uniform reservoir (CHUR). Some portion of the modern mantle has been depleted in incompatible trace elements such as Sm and Nd. The following table contains the approximate isotopic composition of this depleted mantle reservoir and CHUR:

Sample	^{143}Nd/^{144}Nd	^{147}Sm/^{144}Nd
CHUR	0.512538	0.1967
Depleted Mantle	0.513051	0.2137

Make a single figure (your Figure 1) with a line illustrating how ^{143}Nd/^{144}Nd in CHUR and the depleted mantle evolve over the history of Earth (4.543 Ga to today). Make sure it is clear which line represents which reservoir through a legend or annotation. Your x-axis should be the age (years before present), and the y-axis should be the isotopic ratio. Have CHUR and the depleted mantle had the same Nd isotopic composition in the past? Approximately when?

(d) (2 points) Variations in ^{143}Nd/^{144}Nd between reservoirs are usually quite small. A convention for describing these small variations is to define a new scale relative to the CHUR model, known as the epsilon Nd (ϵNd).

$$\epsilon\text{Nd} = \frac{\left(\frac{^{143}\text{Nd}}{^{144}\text{Nd}}\right)_{\text{SAMPLE}} - \left(\frac{^{143}\text{Nd}}{^{144}\text{Nd}}\right)_{\text{CHUR}}}{\left(\frac{^{143}\text{Nd}}{^{144}\text{Nd}}\right)_{\text{CHUR}}} \times 10000$$

Make a new figure showing the evolution of CHUR and depleted mantle over Earth History using the ϵNd scale (change the y-axis from Figure 1 to ϵNd). This new figure will be your Figure 2 and you will add components to it over the next few questions. What is the ϵNd of the depleted mantle?

(e) (2 points) You will use this Sm-Nd isotopic system to investigate an ancient layered igneous complex. This suite of rocks consists of layered mafic-felsic plutonic rocks. These rocks are of particular interest to you because a previous study, which examined whole rock major and trace element concentrations, concluded that the entire suite of rocks was derived from different degrees of melting of the mantle in response to several discreet phases of mantle plume activity. A later study analyzed the Rb/Sr isotopes and placed a number of rocks of varying compositions on an isochron and concluded the age of superplume activity was **2.513±0.156 Ga**. You contacted the authors of these papers and asked for some samples to do your work on, and they sent you a single sample of rather strange, garnet-bearing charnokite. The first thing you do is measure the whole-rock Sm-Nd isotopes:

Sample	$^{143}Nd/^{144}Nd$	$^{147}Sm/^{144}Nd$
Whole Rock	0.512683	0.1919

Plot how your whole rock $^{143}Nd/^{144}Nd$ has evolved over time. Add this to your Figure 2 (make sure you convert to the epsilon Nd scale). When last was this sample in equilibrium with the depleted mantle? Could this charnockite have formed during the superplume activity at **2.513±0.156 Ga**?

(f) (3 points) You then crush the charnokite and get mineral separates. You analyze the mineral separates for Sm-Nd isotopes and get the following results:

Sample	$^{143}Nd/^{144}Nd$	$^{147}Sm/^{144}Nd$
Garnet	0.512883	0.2052
Orthopyroxene	0.512761	0.1984
Plagioclase	0.512533	0.1797
Orthoclase	0.512558	0.1813

Add the ϵ Nd evolution lines for each mineral phase to your Figure 2. Only plot the ϵ Nd of the mineral phase from today to the time when it intersects the whole rock evolution. Assume the charnockite forming melt has been a closed system since it was extracted from the depleted mantle. In what order did the four mineral phases crystallize?

(g) (3 points) You will now determine an isochron age for this sample. First, plot (your Figure 3) the mineral separate $^{147}Sm/^{144}Nd$ (x-axis) versus $^{143}Nd/^{144}Nd$ (y-axis). Plot an isochron (line) through the mineral phases that you believe:

Have the same age

Have the same initial child isotopic composition

What is the slope and age of your isochron?

(h) (3 points) Compare you isochron age to the age when the charnockite melt was extracted from the depleted mantle. Describe a geologic history that could explain both ages.