Isotopes Class 12.744 Problem Set #4

Assigned: November 29, 2012

Due: December 11, 2012

1. (Super Problem) Determining Pb scavenging rates in the abyssal North Pacific. Consider the accompanying spreadsheet (PS4Data.xlsx). It contains on the first sheet a profile of hydrographic data (temperature, potential temperature, salinity, etc. vs. depth) from a location in the eastern subtropical North Pacific. The second sheet lists some ^{210}Pb and ^{226}Ra activities (including uncertainties), in units of decays per minute per 100 kg of seawater, as a function of depth at the same location. Assume a half-life of 1600 years for ^{226}Ra and 22.3 years for ^{210}Pb.
    a. Given that these two isotopes are in the same (^{238}U) decay chain, what do their relative activities tell you about their relative chemistries? What is happening?
    b. Using the mean activities of these isotopes below 2000m depth, do a simple box model calculation to estimate the time-scale associated with particle scavenging of lead from the water column.
    c. Construct a one dimensional advection-diffusion-production/consumption-decay model to solve for the rate of *in situ* Ra remineralization in the water column and the timescale of Pb scavenging, using the following strategy:
        i. Assume a one-dimensional (vertical) advective-diffusive sub-range between 1000m and 4100m depths, using a coordinate system with z=0 at 4100m and z=3100 at 1000m depths.
        ii. Use the potential temperature profile over this range to solve for K/w using the stable-conservative advection-diffusion equation outlined in class.
        iii. Assuming that w = 5 m/y (i.e., upwelling upward), solve the non-conservative radioactive decay equation and its analytic solution described in class to compute the ^{226}Ra profile that most closely fits the data provided and to find its production rate (J in units of dpm/100kg/year). You can do this either in MATLAB or EXCEL. To keep it simple, start with an educated guess for J and manually try & plot the profiles to find a best "chi-by-eye" fit. If you're feeling ambitious, you can use a MATLAB optimizer to find the best match between data and model, or use the EXCEL "goal seeker" capability. Try doubling and halving the J value that you arrive at, plotting the resultant curve, and explain qualitatively what's happening.
        iv. Using the optimal Ra profile from (iii), and the more complex analytic solution for the coupled equation described in class, use the same strategy to fit the ^{210}Pb profile and find the optimal value of the Pb scavenging time-scale. You can use your estimated timescale from part (b) as a starting point. Demonstrate and explain the effect of halving and doubling the optimal time-scale.

2. In many respects the geochemistry of strontium in seawater is similar to that of calcium. Consider seawater a two-component mixture of 25 weight% hydrothermal strontium and 75 weight% riverine strontium. Calculate the isotope composition of seawater strontium from the following values:

Hydrothermal fluids: $^{88}Sr/^{86}Sr$ = 0.27 per mil, $^{87}Sr/^{86}Sr$ = 0.703

River water: $^{88}Sr/^{86}Sr$ = 0.31 per mil, $^{87}Sr/^{86}Sr$ = 0.711

Use a standard $^{88}Sr/^{86}Sr$ of 8.375209 (zero per mil) and a $^{84}Sr/^{86}Sr$ of 0.056584.

Use the two-component mixing equation conventionally used in stable isotope geochemistry to calculate the $^{88}Sr/^{86}Sr$ and $^{87}Sr/^{86}Sr$ values of seawater. What are the $^{87}Sr/^{86}Sr$ and $^{88}Sr/^{86}Sr$ values of your mixture (i.e. seawater)? **(15 points)**

3. Measurements of seawater $^{88}Sr/^{86}Sr$ yield a delta value of 0.38. How do you explain this value in the context of the calculation above? **(15 points)**

4. Imagine you are investigating an ocean on a different habitable planet of similar size to Earth that has an identical strontium budget to Earth's ocean except that the average riverine $^{87}Sr/^{86}Sr$ value is 10 instead of 0.711. Redo the two-component mixing calculation

a) using the same approach as in part 2.

b) using proper atomic weights in your mixing calculation.

Comment on your findings. **(15 points)**

Extra Credit (5 points): What mechanism(s) could make the average riverine $^{87}Sr/^{86}Sr$ value of this habitable planet so different from rivers on Earth?