Marine Chemistry 12.742
Problem Set #7

Question 1

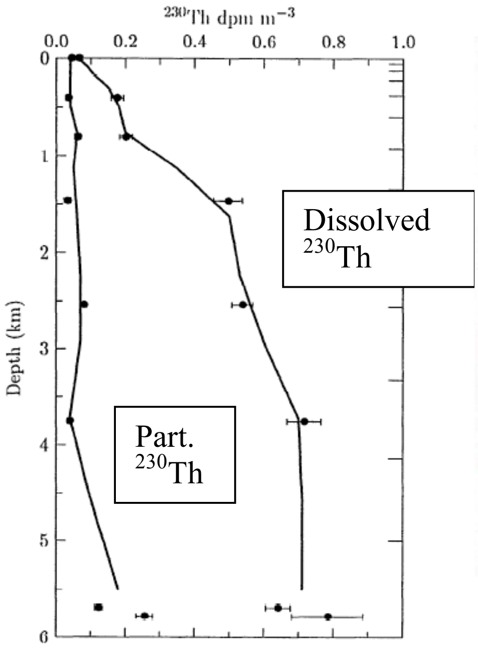
Deep-water thorium dynamics. Given the dissolved and particulate ^{230}Th, ^{228} Ra and ^{228}Th data in the table and figure below. Recall that ^{234}U decays to ^{230}Th and ^{228}Ra decays to ^{228}Th:

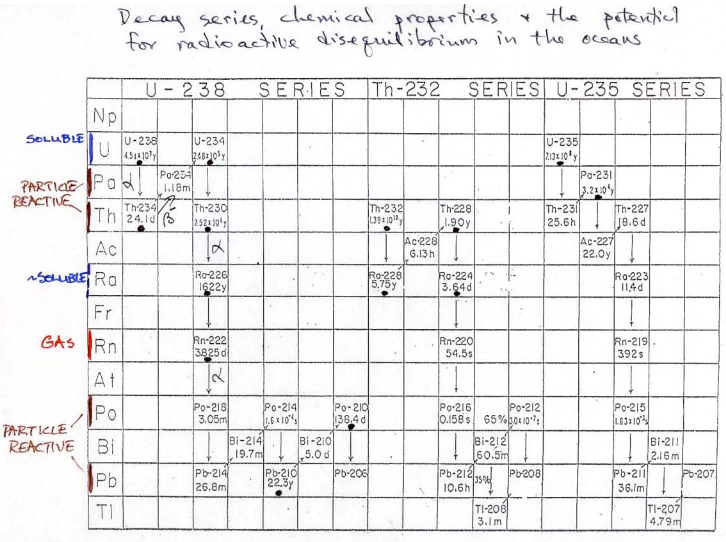
a) Compute the expected ^{230}Th flux reaching the seafloor at 6000m (from 234U) and a mean particle sinking speed (given an approximation of the particulate ^{230}Th profile)

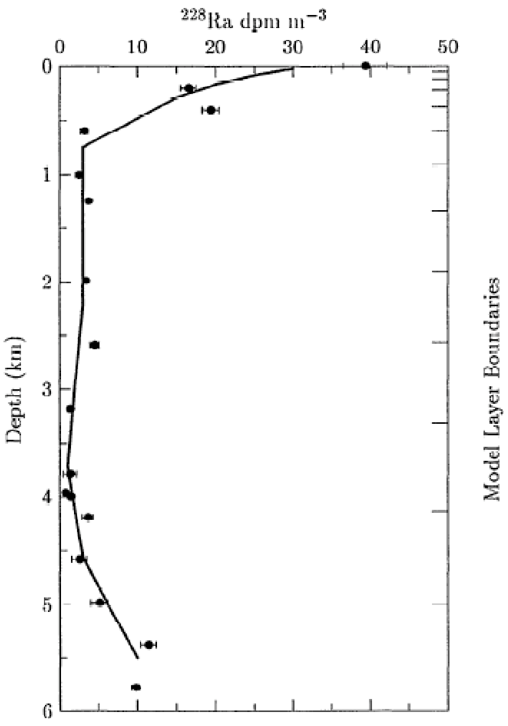
b) Estimate values for the forward and backward scavenging coefficients k_1 and k_{-1} for a simple, two-box dissolved-small particle reversible scavenging model (the one from class) (Note: when you solve the equations for a single Th isotope you will have two equations and 3 unknowns, w the sinking speed, k_1 and k_{-1}. Adding an additional isotope system adds additional constraints. Do NOT make this into a full data analysis; eyeball some values—I just want you to get familiar with the equations and what the data might look like).

c) Write out the equations of ^{230}Th for 3-box (dissolved, small particle, large particle) scavenging & particle aggregation/disaggregation model schematic shown below.

d) Median radionuclide-based model estimates for beta$_2$ and beta$_{-2}$ are 3 y-1 and 150 y-1, respectively. How would you interpret these values? What does it say about organic matter cycling.




Decay series, chemical properties + the potential for radioactive disequilibrium in the oceans



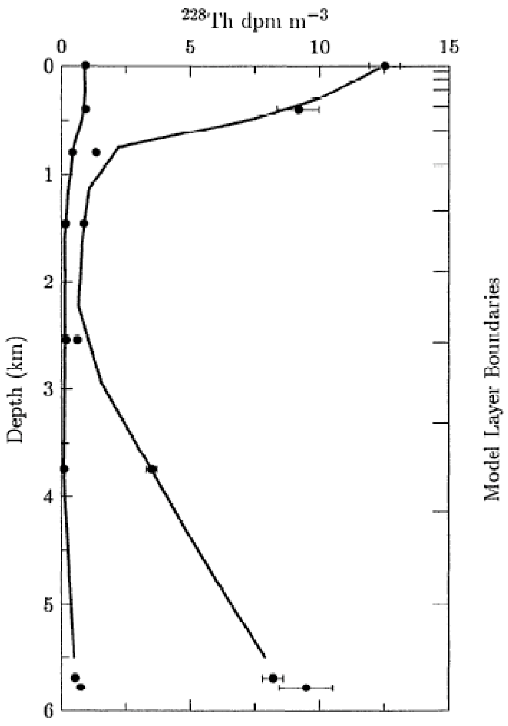
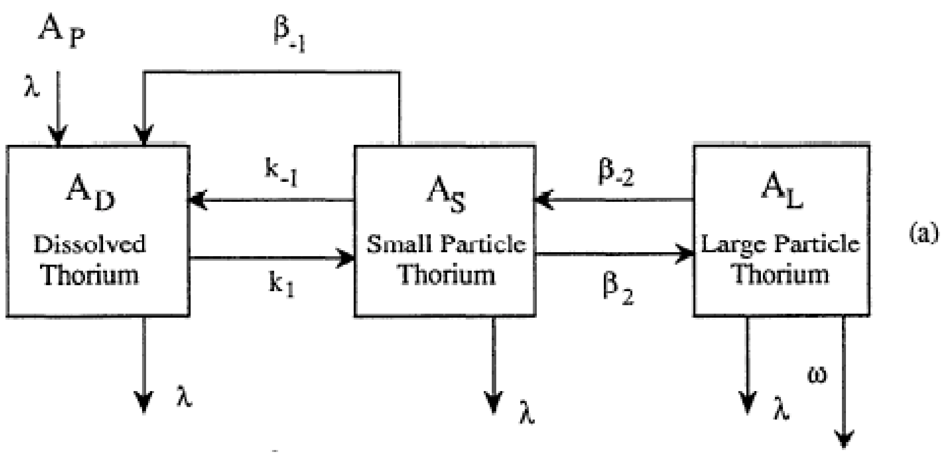
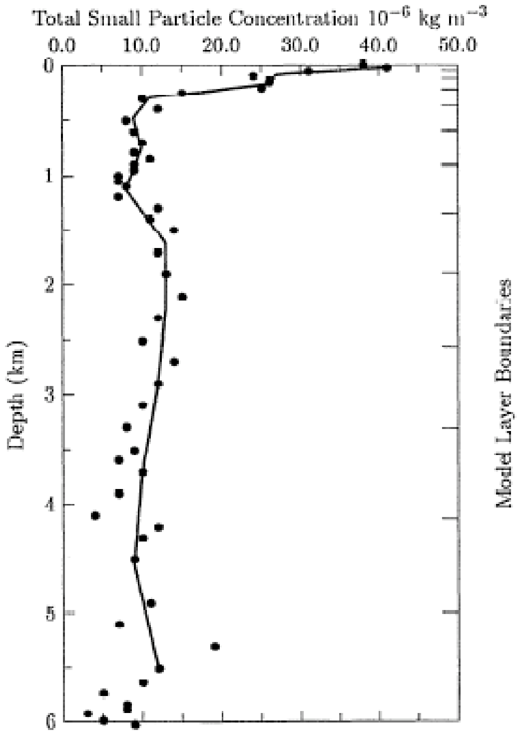
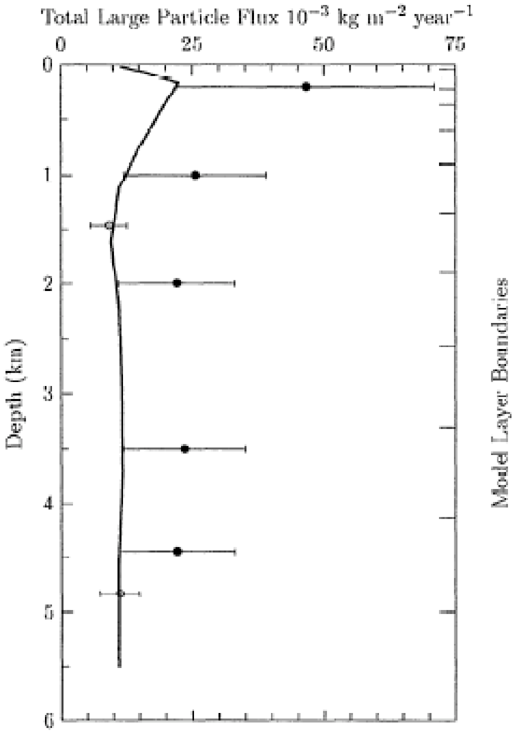


Table 2. Initial Estimates of Thorium and Radium Activity

Depth, m	Layer Thickness, m	Dissolved ^{228}Ra, dpm m^{-3}	Dissolved ^{230}Th, dpm m^{-3}	Dissolved ^{228}Th, dpm m^{-3}	Small-Particle ^{234}Th, 10^6 dpm kg^{-1}	Small-Particle ^{230}Th, 10^3 dpm kg^{-1}	Small-Particle ^{228}Th, 10^3 dpm kg^{-1}
25.5	50.9	3.0	0.07	12	-	1.0±0.1	22.0±3.1
85.1	68.4	2.5	0.09	12	-	1.5±0.2	33.5±4.7
169.5	100.4	2.0	0.11	11	-	1.5±0.2	35.0±4.9
295.3	151.1	1.5	0.15	10	9±1	3.6±0.5	83.2±11.7
482.8	224.0	1.0	0.18	7.6	11±1	4.4±0.6	90.0±12.7
754.6	319.6	3.0	0.20	2.2	10±1	6.0±0.8	47.0±6.6
1130.7	432.5	3.0	0.35	1.1	12±1	6.3±0.9	33.8±4.8
1622.4	551.0	3.0	0.50	0.8	8±1	4.6±0.7	10.0±1.4
2228.4	660.9	3.0	0.53	0.7	8±1	5.4±0.8	11.5±1.6
2934.8	751.9	2.0	0.60	1.5	8±1	5.8±0.8	10.8±1.5
3720.9	820.4	1.0	0.70	3.4	10±1	4.0±0.6	8.0±1.1
4565.5	868.9	3.0	0.71	5.5	11±1	11.1±1.6	28.9±4.1
5500.0	1000.0	1.0	0.71	7.9	8±1	15.0±2.1	40.0±5.7







Question 2

A moored sediment trap has been deployed for exactly one year at 3000m in the central gyre of the Atlantic. The trap has an aperture of 0.5 m^2 and collected 10.2g of settling material.

Analysis of the material collected by the sediment trap for ^{238}U, ^{230}Th and ^{231}Pa gives:

^{238}U = 0.20 dpm/g
^{230}Th = 3.00 dpm/g
^{231}Pa = 0.125 dpm/g

a) Assuming that all the ^{238}U is present in the mineral lattice of clay minerals in which the U-decay series is in secular equilibrium, calculate the flux of scavenged ^{230}Th and ^{231}Pa intercepted by the sediment trap (for the latter, you will need to calculate the activity of ^{235}U, assuming natural isotopic abundance. Consult http://ie.lbl.gov/toi/ for needed information).

Knowing that the ^{230}Th and ^{231}Pa produced in the water column (P_{Th}; P_{Pa}) are removed in different proportion by vertical scavenging (V_{Th}; V_{Pa}) and horizontal transport to the margins (H_{Th}; H_{Pa}) and knowing that the ratio of the horizontal transport rate of the two nuclides $R_H = H_{Th}/H_{Pa} = 2$, calculate:

b) The fraction of ^{230}Th and ^{231}Pa produced in the water column of the central gyre that is removed by the vertical flux of particle in the central gyre region or by lateral transport to the margins.

c) The trapping efficiency of the sediment trap that was deployed and the vertical flux of material corrected for inaccuracies in trap collection.

Problem 3

A water sample taken from the deep Atlantic within the NADW has the following characteristics:

Pot. Temp.: 2°C
Salinity: 35 psu
$[NO_3^-] = 21.5$ μmoles/kg
[Phosphate] = 1.45 μmoles/kg
$[O_2] = 250$ μmoles/kg
$[\Sigma CO_2] = 2180$ μmoles/kg
CA = 2300 μmoles/kg

Calculate, using the revised Redfield Ratios of Anderson and Sarmiento ($P/N/-O_2/C_{org}$ = 1/16/170/117):

a) The number of moles of organic carbon that has been oxidized and the number of moles of calcium carbonate that has dissolved per kg of seawater during the transit time of deep water from its site of formation in the N. Atlantic to the site where the sample was collected.
b) Preformed nitrate, phosphate, and ΣCO_2 concentration.
c) How large is the increase in $[Ca^{2+}]$ relative to its average concentration in seawater?
d) The number of additional moles of organic carbon that needs to be oxidized to deplete all the remaining oxygen.
e) The number of additional moles of organic carbon that would have to be oxidized under anaerobic conditions to subsequently deplete all the available nitrate. First assume that the nitrate reducers only oxidize carbohydrates, then calculate how much more nitrate per moles of C oxidized is required when nitrate oxidizers oxidize organic matter with the chemical formula ($CH_{2.72}O$)

Seawater O_2 concentration in equilibrium with the atmospheres at 2°C and 35 permil salinity = 331.8 μmoles/kg

Use the relationship: Total Alkalinity = 547.05 + (50.56 x salinity) to estimate preformed carbonate alkalinity.