1. Carbonate System Processes (organic matter)
As a result of respiration of organic matter in seawater (true/false; then state why in each case)(12):
   a. $\text{PCO}_2$ goes down (3)
   b. pH goes up (3)
   c. alkalinity goes up (3)
   d. DIC goes down (3)

2. What controls the composition of seawater?
   a) Describe the concept of the kinetic model as a control on the composition of seawater. (10)
   b) What controls the concentration of $\text{Ca}^{2+}$ in seawater? (5).
3. Ocean carbonate reactions (use of CO2Calc not allowed)

a) The concentration of carbonate ion (CO$_3^{2-}$) is important to know to understand carbonate mineral solubility reactions. Calculate the concentration of CO$_3^{2-}$ in surface seawater near Hawaii if you know the pH and P$_{CO2}$. There are two steps. First you calculate DIC (or C$_T$) and then CO$_3^{2-}$.

Assume the apparent equilibrium constants for seawater of $K'_H = 10^{-1.5}$, $K'_1 = 10^{-6.0}$ and $K'_2 = 10^{-9.0}$. Assume pH = 8.1 and P$_{CO2} = 395$ (10 pts)

b) We can write the solubility of CaCO$_3$ in terms of Ca$^{2+}$ and CO$_3^{2-}$ as follows:

\[ \text{CaCO}_3 = \text{Ca}^{2+} + \text{CO}_3^{2-} \]

The apparent equilibrium constant ($K'_s$) for this reaction = $4.26 \times 10^{-7}$ or $10^{-6.37}$

Calculate the equilibrium concentration of CO$_3^{2-}$ if you know the concentration of Ca$^{2+}$ in seawater. Assume that the concentration of Ca$^{2+} = 10.5 \times 10^{-3}$ M. (10 pts)

c) What is the degree of saturation ($\Omega$) of calcite in surface seawater (CO$_3^{2-}$ from part a). (10)

d) What would be the pH if surface seawater was at equilibrium with CaCO$_3$ ($\Omega = 1.0$) (10). (Use CO$_3^{2-}$ from part b)
4. Stable Isotopes
During photosynthesis the following schematic reaction occurs.

\[ \text{CO}_2 + \text{H}_2\text{O} \rightarrow \text{CH}_2\text{O}_{\text{om}} + \text{O}_2 \]

If \( \delta^{13}\text{C} \) of \( \text{CO}_2 = 5 \%/00 \)
and \( \delta^{13}\text{C} \) of \( \text{CH}_2\text{O}_{\text{om}} = -12 \%/00 \)

a) What is \( \varepsilon \) for this reaction? (5)

b) Is \( ^{13}\text{C} \) enriched or depleted in the product compared to the reactant? (5)

c) Give a possible reason for the difference in \( \delta^{13}\text{C} \) between the product and the reactant. (5)
5. Secular Equilibrium
a) Explain (using words and graphs only) the criteria for secular equilibrium (5) and explain why it is important (5) to the application of U-Th isotopes in oceanography. Use an example. (10)

b) If there was some seawater with some $^{238}\text{U}$ ($4.5 \times 10^9$ yr) but no $^{234}\text{Th}$ (24 days), and only radioactive decay was occurring, how long would it take before the activity of $^{234}\text{Th}$ equally half that of $^{238}\text{U}$? (5)

c) How long would it take before their molar concentrations were equal? (5)
6. Ocean Distributions of Inorganic Carbon

Dissolved Inorganic Carbon (DIC) and Alkalinity increase in the deep ocean from the Atlantic to the Pacific.

<table>
<thead>
<tr>
<th></th>
<th>DIC</th>
<th>Alkalinity</th>
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</thead>
<tbody>
<tr>
<td>Deep Atlantic</td>
<td>2200 μM</td>
<td>2360 μM</td>
</tr>
<tr>
<td>Deep Pacific</td>
<td>2350 μM</td>
<td>2400 μM</td>
</tr>
</tbody>
</table>

How much of this increase is due to respiration of organic matter and how much is due to CaCO₃ dissolution? (10)