

## Introduction to Chemical Oceanography

### Problem Set 2

Posted 24 Oct., 2019

Due 5 Nov., 2019

All answers are to be submitted by email to both [maltabet@umassd.edu](mailto:maltabet@umassd.edu) and [amnich@umassd.edu](mailto:amnich@umassd.edu) either in MS Word or Excel format. Deadline for submission is 12:30 PM on Nov. 5. Late submission will result in the loss of 1 point per day from the 10 point total. You are strongly encouraged to review the problems early to clarify any questions you might have. Do not wait to the day before to ask for assistance, as there may not be a chance to respond. Use email to ask specific questions. This problem set is designed to be open book and open notes, but you are expected to work individually to obtain your answers. Essays and short answers must be in your own words. You should show all your work and clearly delineate how you derived your results where pertinent. This problem set constitutes 12.5 % of your overall grade. **You are expected to work independently to solve these problems.**

USE ONLY MOLINITY UNITS AND ASSUME THAT pH IS DIRECTLY CONVERTED TO [H+] AND IS EQUIVALENT TO ITS ACTIVITY

- (1.0) 1. Does the alkalinity of water (isolated from its surroundings) increase, decrease or stay the same as small quantities of the following are added? Briefly explain. Assume complete disassociation of ionic compounds.



- (3.0) 2. A. Using appropriate equations and pK values from the lecture slides, calculate the concentrations of the carbonate system species in  $\mu\text{mol/kg}$  for seawater at  $15^\circ\text{C}$  and  $S = 35$  at pH 8.00 in equilibrium with current atmospheric  $p\text{CO}_2$  of  $408.55 \mu\text{atm}$  ([www.co2.earth](http://www.co2.earth)). What is the total dissolved inorganic carbon concentration and carbonate alkalinity for this solution in  $\mu\text{mol/kg}$ ? Calculate the saturation state for calcite and aragonite. Is this solution undersaturated or supersaturated with respect aragonite and calcite. HINT: convert  $p\text{CO}_2$  from  $\mu\text{atm}$  to  $\text{atm}$  to get results in  $\text{mol/kg}$ , then convert to  $\mu\text{mol/kg}$ . Compare results with those using the Excel calculator “co2sys ver25”.

B. Given ‘business as usual’, late this century or early next, atmospheric  $p\text{CO}_2$  may reach  $1100 \mu\text{atm}$ . ASSUME: that carbonate alkalinity ( $A_c$ ) is the same as in part A and equivalent to total alkalinity. Given surface seawater at equilibrium with this doubling of  $p\text{CO}_2$ , what are the values for the parameters you calculated in part A? Has the saturation state for aragonite and calcite changed and if so what are the ramifications for ocean biology? HINT: calculate for different values of lowered pH until the  $A_c$  value in part A is matched. Compare results with those using the Excel calculator “co2sys ver25” but using instead the same total alkalinity as in part A.

- (2.0) 3. A. Explain in terms of chemical equilibria why each of the parameters (except  $\Delta\text{CO}_2$ ) listed in lecture slide Table 7.6 changes (or does not) in the direction indicated as a result of the oxidation of organic matter. Predict and explain the corresponding changes in a water mass as it ages in the ocean's interior.
- (2.0) 4. Explain in terms of chemical equilibria why each of the parameters (except  $\Delta\text{CO}_2$ ) listed in lecture slide Table 7.7 changes (or does not) in the direction indicated as a result of  $\text{CaCO}_3$  dissolution. In this light, describe how a plot of total Alk vs. total  $\text{CO}_2$  for an ocean water mass can tell you the relative proportions of organic matter oxidation and  $\text{CaCO}_3$  dissolution.
- (2.0) 5. In a brief essay, answer the following questions; What are the carbonate saturation, carbonate compensation, and lysocline depths, giving examples? Describe how carbonate equilibria determine these depths; illustrate with pertinent equation(s) for saturation state and graph(s) of vertical variations. Why and how is increasing atmospheric  $\text{CO}_2$  likely to change both  $\text{CaCO}_3$  production in surface waters and its preservation in deep-sea sediments.