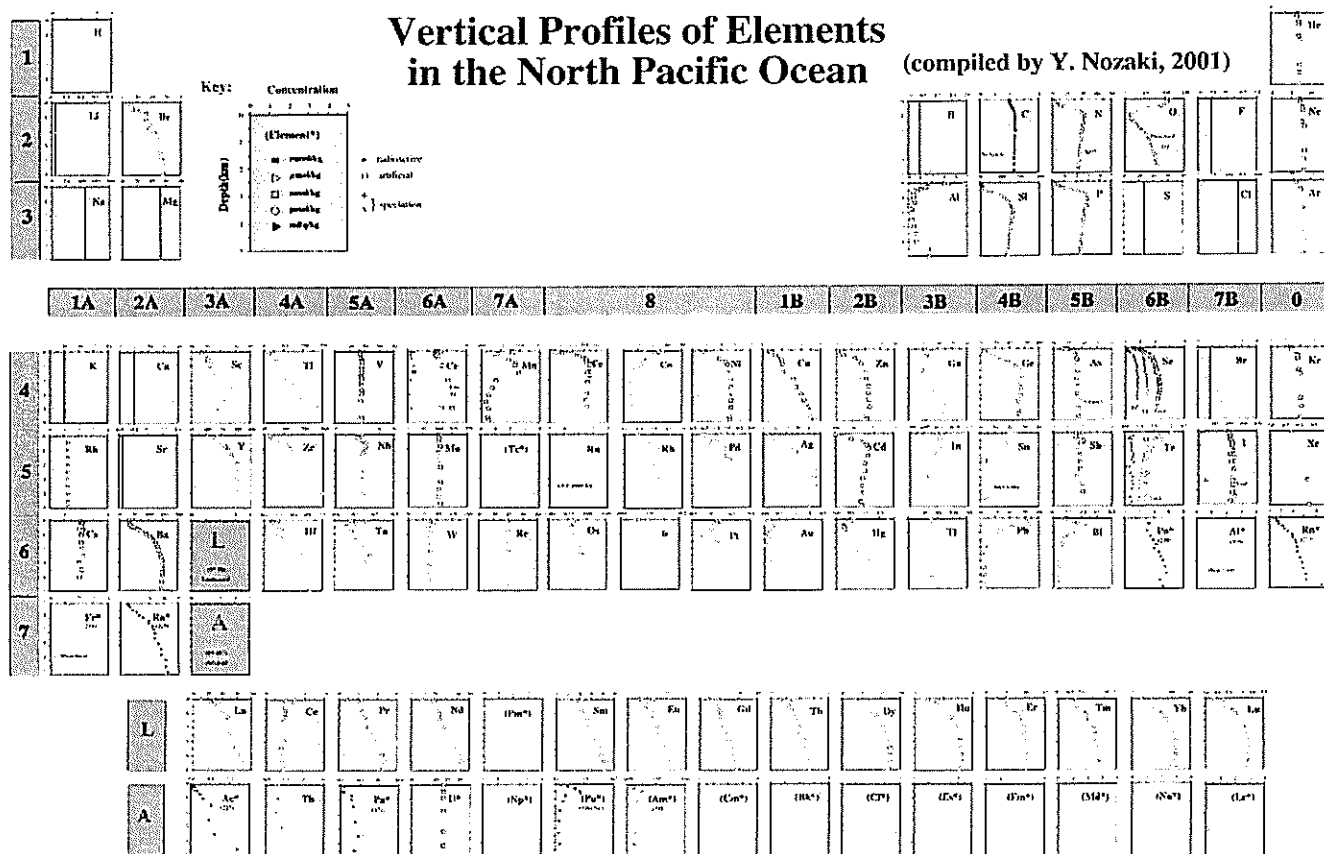


**1. Terminologies commonly used in Chemical Oceanography (20%)**

- (1) List the 6 most abundant ions in seawater. Why do these elements behave conservatively? (4%)
- (2) What do “nutrients” mean? (2%) List at least 6 nutrient-type elements in the ocean? (2%) Why do their depth profile shows an depletion in the surface, increase with depths but then decrease again? (4%)
- (3) Why is iron concentrations so low in the ocean despite it is one of the most abundant elements on earth? (4%) What are the sources of iron to seawater? (2%) What is iron-limitation? (2%)

For your information, the Nozaki Table is provided below.



**2. Oxygen concentrations in seawater. (25%)**

- (1) What are the roles of dissolved oxygen in the ocean? (5%)
- (2) Based on figure 1, why are higher concentrations of dissolved oxygen higher in Atlantic deep water than in the Pacific deep water at 47 °N? (5%) Why is there little difference between the oxygen concentrations at the 45 °S in the Atlantic Ocean and the Pacific Ocean? (5%)
- (3) Why are higher oxygen concentrations in the surface seawater than in the deep ocean? (5%)
- (4) Which depths do oxygen minimum zones (OMZ) occur? Why do OMZ occur at these depths? (5%)

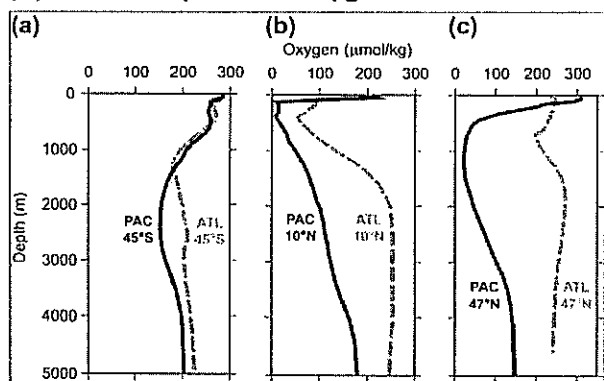


Figure 1. Oxygen concentrations in seawater.

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3. Dissolved inorganic carbon (DIC) in the ocean. (40%)

- (1) What are the species of dissolved inorganic carbon in the ocean? (2%)
- (2) Which form dominates in the ocean and why? Please use Figure 2 as your information. (4%)

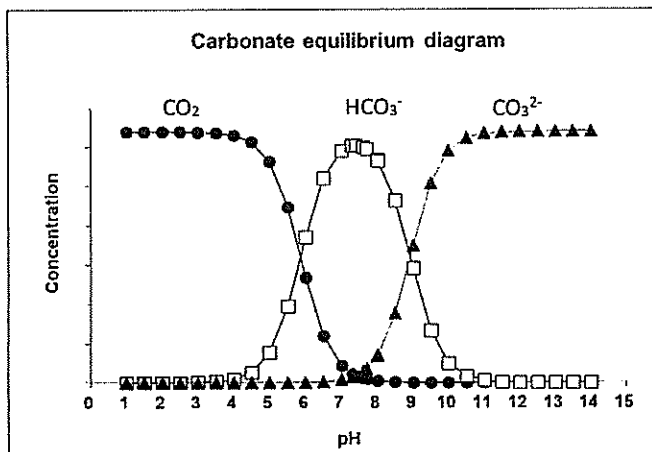


Figure 2. Carbonate equilibrium diagram.

- (3) What is the approximate dissolved inorganic carbon concentration in the ocean? (4%) [units must be provided]
- (4) Write down the equation describing what happens when  $\text{CO}_2$  dissolves in seawater? (5%)
- (5) Based on Figure 3, how does  $\text{CO}_2$  concentration vary with time in the atmosphere? How does  $\text{CO}_2$  concentration vary in the seawater at the Station Aloha near Hawaii (subtropical North Pacific Ocean)? Why are there seasonal variations? Is there a long-term trend? If so, what is the average rates of increase for atmospheric  $\text{pCO}_2$  and seawater  $\text{pCO}_2$ ? (10%)
- (6) List possible physical, chemical and biological factors controlling the  $\text{CO}_2$  concentrations in the ocean. (5%)
- (7) Why may an increase in atmospheric  $\text{CO}_2$  result in a decrease in ocean seawater pH? (5%)
- (8) Is it possible that the global seawater may become acidic? Why or why not? (5%)

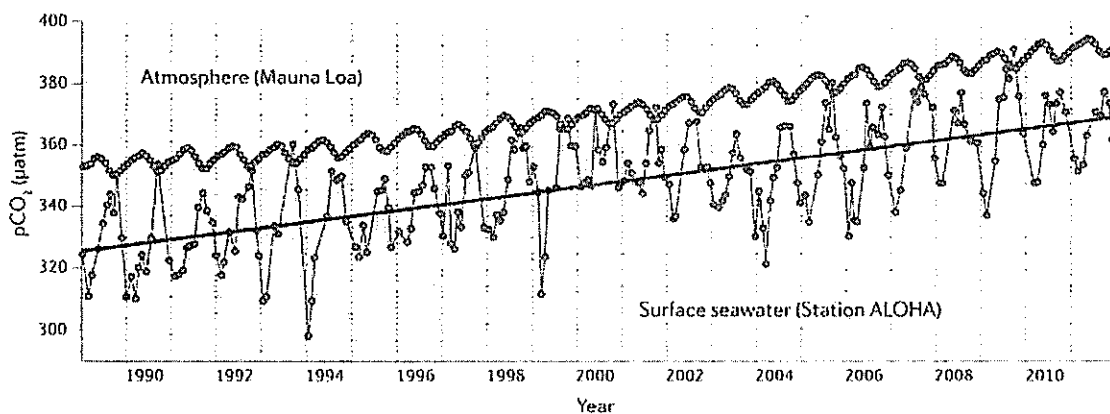


Figure 3.  $\text{CO}_2$  concentrations in the atmosphere and  $\text{CO}_2$  & pH in North Pacific seawater. Adapted from Karl and Church (2014).

4. Dissolved organic carbon (DOC) in the ocean. (15 %)

- What is the definition of an organic compound? (5%)
- Calculate the (1) particulate organic carbon and (2) dissolved inorganic carbon (DIC) content in the ocean based on the statement below. "The inventory of oceanic DOC is estimated to be  $\sim 662 \pm 32$  Pg C, 200 times the mass of the organic carbon in suspended particles but approximately 1/50th of the total DIC inventory (Hansell et al. 2009)". (5%)
- Based on Figure 4, please describe how the estimation of the carbon contents of each DOC fraction is done? You must show your calculations. (5%)

Note: RDOC-refractory DOC, SRDOC-semi refractory DOC, SLDOC-semi labile DOC and LDOC-labile DOC

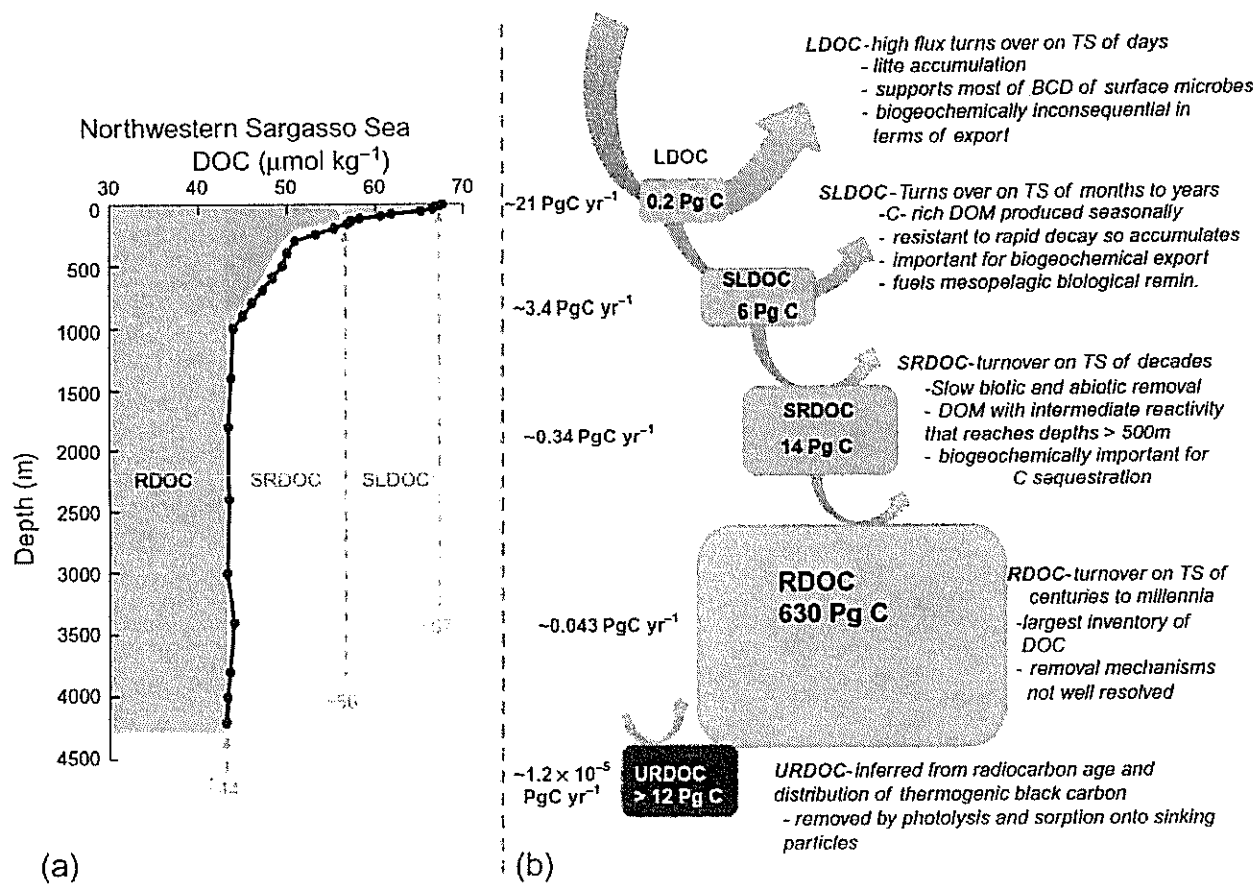


Figure 4. (a) DOC fractions, defined by reactivity, in the oceanic water column. Vertical distribution of the RDOC, SRDOC, and SLDOC pool (shaded areas) and the estimated range of DOC concentrations observed within those pools observed in stratified oligotrophic waters such as that of the Northwestern Sargasso Sea. (b) Estimated inventories (in box) and removal rates (figure to left of box) of each fraction of DOM. TS is time scale. Adapted from Hansell (2013).

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