

1. Common Terminologies in Chemical Oceanography (40%)

- (1) What is the definition of salinity? How do oceanographers measure salinity? (4 %)
- (2) What factors may decrease the salinity of surface seawater in a particular region? (4 %)
- (3) Based on Figure 1, select from the following elements that behave conservatively in the ocean (4 %)

Ca, P, K, Na, O, Cl, Mg, Pb, Ca, Fe, Cu, Zn
- (4) Why do some elements behave conservatively? (4 %)
- (5) Based on Figure 1, which are the top three major nutrients (in micro molar concentrations) that have nutrient-like profiles in the ocean? (3 %)
- (6) Why do some elements show depletion in the surface seawater and become abundant in the deep water (5 %)?
- (7) List at least four trace metals that are important to marine life? [Hint: those with nutrient-like profiles] (4%)
- (8) What is Thermohaline Circulation? Please describe changes in nutrients, oxygen and total dissolved inorganic carbon during the Thermohaline Circulation. (4 %)
- (9) Based on Figure 1, please describe the depth distribution of element Pb in the ocean water column and provide the possible controlling mechanisms (4%).
- (10) What are the numbers for the Redfield Ratio? Given as C:N:P by Redfield, 1934. (4 %)

C:N:P=

1:16:106 ?

16:1:106 ?

106:16:1 ?

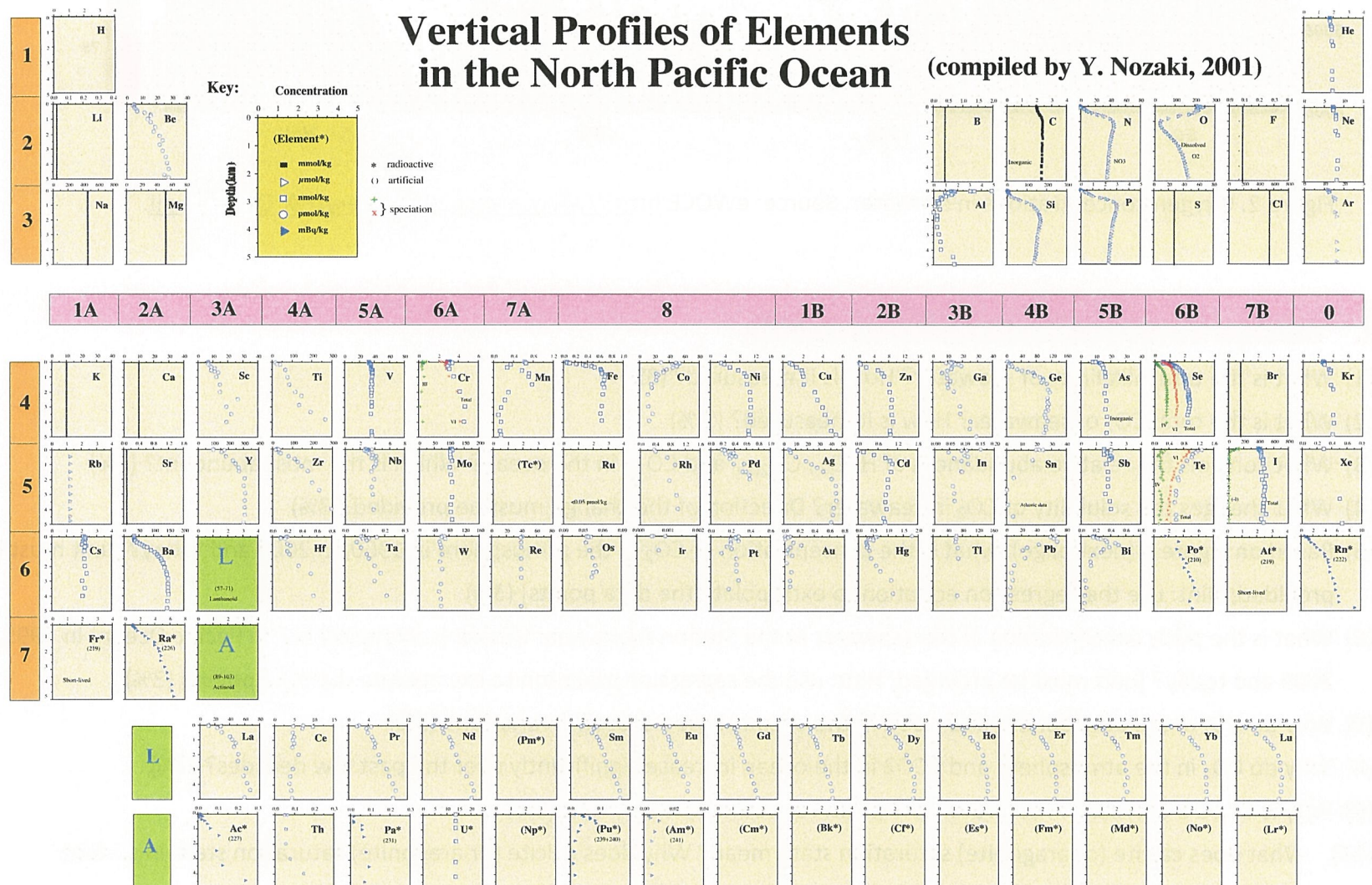


Figure 1. Concentrations of elements in seawater. Source: Nozaki, 2001.

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2. Oxygen concentrations in seawater (30%)

- (1) What are the sources of the dissolved oxygen in the ocean? (5%)
- (2) What are the removal mechanisms of the dissolved oxygen in the ocean? (5%)
- (3) Based on figure 2, data from the World Ocean Circulation Experiment (WOCE) Western Pacific Ocean line p09, please describe the general variations in oxygen concentrations with depths? (5%)
- (4) Why are oxygen concentrations in the surface ocean at 30 °N much higher than those in the equatorial region? (5%)
- (5) What is AOU (apparent oxygen utilization)? At the 30 °N, please rank the seawater from the surface, 1200m and 3000m with the highest AOU to the lowest AOU? (5%)
- (6) Please describe the relationship, if any, between AOU and oxygen minimum zone? Where did you find the oxygen minimum zone along the P09 surveyed line (5%)?

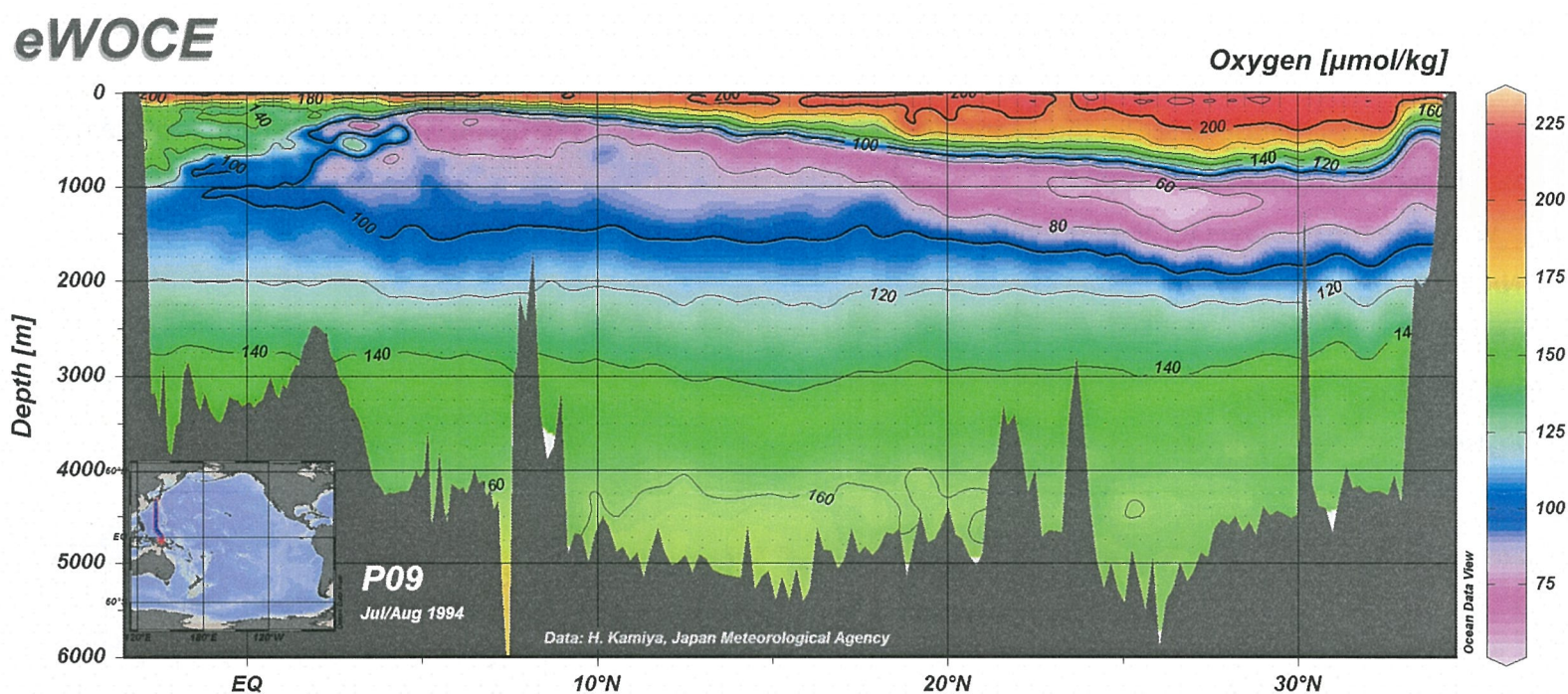
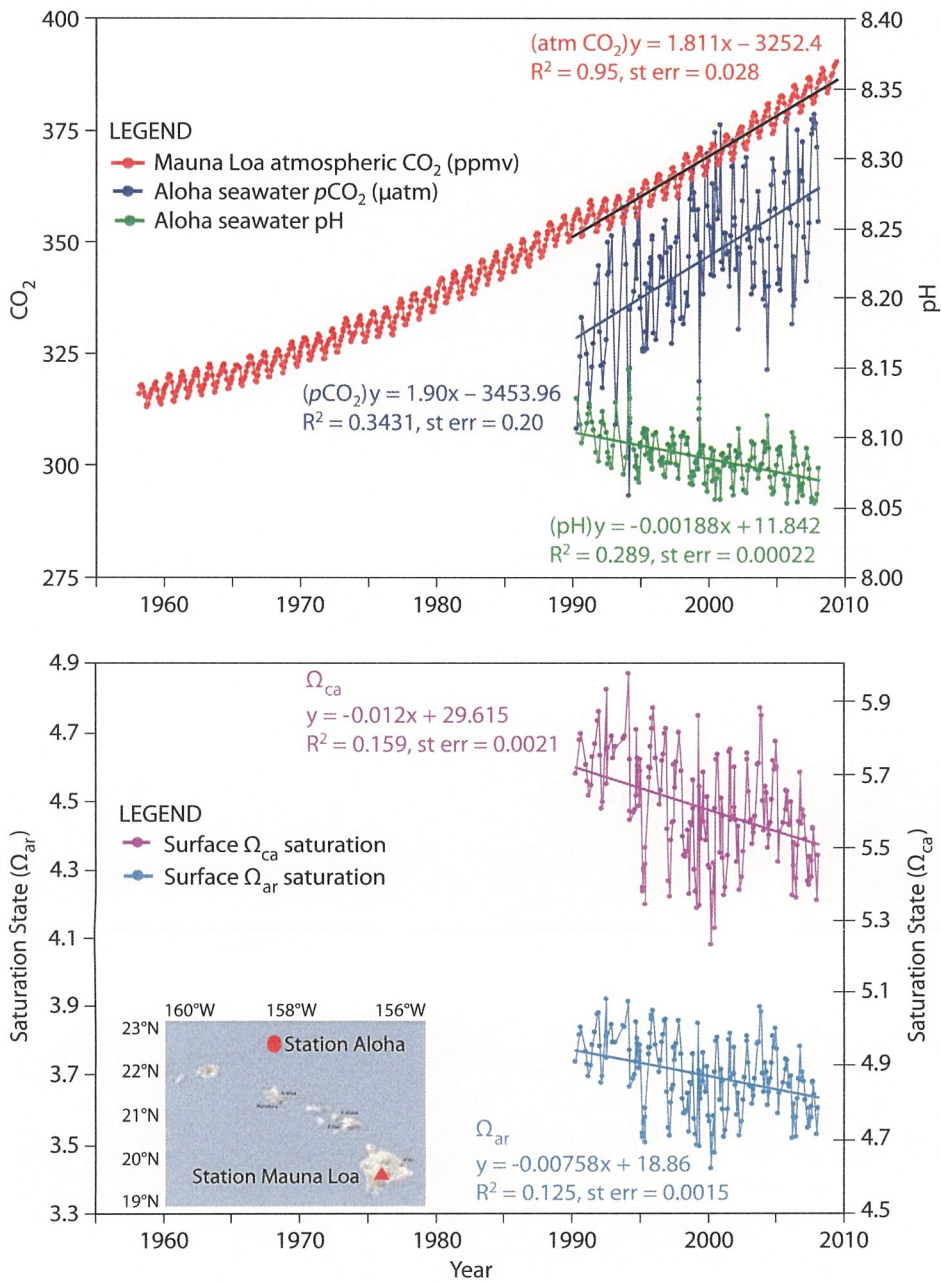


Figure 2. Oxygen concentrations in seawater. Source: eWOCE http://www.ewoce.org/gallery/P9_OXYGEN.gif.

3. Dissolved inorganic carbon (DIC) in the ocean. (30%)

- (1) What is the total alkalinity of seawater? How is it measured? (3%)
- (2) What is the total CO₂ of seawater? How is it measured? (3%)
- (3) What controls the relative abundances of HCO₃⁻, CO_{2(aq)} and CO₃²⁻ in the ocean? Which is the most abundant? (3%)
- (4) What changes the solubility of CO₂ in seawater? Direction of the change must be provided. (3%)
- (5) Based on Figure 3 (next page), what is the concentration of CO₂ in the atmosphere in 1960, in 2009 and today? [unit must be provided; Hint: use the regression equation to extrapolate the data points] (3%)
- (6) What is the pCO₂ concentration in the seawater at the Station Aloha near Hawaii (subtropical North Pacific Ocean) in 1995, 2009 and today? [unit must be provided; Hint: use the regression equation to extrapolate the data points] (3%)
- (7) Why do CO₂ in the atmosphere and pCO₂ in the ocean show a seasonal variation? (3%)
- (8) Why do CO₂ in the atmosphere and pCO₂ in the ocean increase significantly over the past few decades? (3%)
- (9) Why is there a decrease in seawater pH? [Hint: related to question # 4] (3%)
- (10) What does calcite (or aragonite) saturation state mean? Why does calcite (or aragonite) saturation state in surface seawater decrease significantly over the past few decades? (3%)



(Top) Time series of atmospheric CO₂ at Mauna Loa (ppmv) and surface ocean pH and pCO₂ (µatm) at Ocean Station Aloha in the subtropical North Pacific Ocean (see inset map). Note that the increase in oceanic CO₂ over the period of observations is consistent with the atmospheric increase within the statistical limits of the measurements. (Bottom) Calcite and aragonite saturation data for surface waters. *Mauna Loa data:* Pieter Tans, NOAA/ESRL, <http://www.esrl.noaa.gov/gmd/ccgg/trends>. *HOT/ALOHA data:* David Karl, University of Hawaii, <http://hahana.soest.hawaii.edu>. Updated from Doney et al. (2009). See also Dore et al. (2009).

Figure 3. CO₂ concentrations in the atmosphere and CO₂ & pH in North Pacific seawater. Source: Feely et al. (2009) Ocean acidification, *Oceanography*, 22(4), p.36-47.

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