OA413 : Climate Dynamics Assignment No. 5

Professor John Shepherd;
SOC, Room 564/03; Tel. (023) 80 596256
John.G.Shepherd@soc.soton.ac.uk

Tuesday 18 March

Due: Monday, 24 March, 2003; 14:00

1) If A represents the anion (negatively charged ion) of an acidic compound, HA, write down the equations for the reversible dissociation reaction in water between HA, and the hydrogen ion H^+ and the acidic anion A^-. Define the equilibrium constant for the dissociation reaction, and use it to explain the difference between a strong acid and a weak acid.

2) The fundamental definition of alkalinity is as the difference between the sum of the molar concentrations of all strong positive ions and that of all strong negative ions

$$\textbf{Alkalinity} = \sum \textbf{strong positive ions} - \sum \textbf{strong negative ions}$$

(a) Explain why this is equivalent to the working definition as

$$\textbf{Alkalinity} = \sum \textbf{weak negative ions} - \sum \textbf{weak positive ions}$$

(b) Acidity is however usually expressed in terms of the pH, which depends only on the hydrogen ion concentration. Explain the relationship (if any) between alkalinity and acidity (as measured by the hydrogen ion concentration). [Remember that the hydrogen ion concentration is only 100 µM/kg even at pH=4.0, which represents moderately acidic conditions, compared with sea-water].

3) (a) Write out the equations for the reversible reactions between CO_2 and water, bicarbonate and carbonate ions, and sketch (without derivation) the concentrations of dissolved CO_2, bicarbonate and carbonate ions, as a function of pH.

(b) The alkalinity of sea-water is significantly positive (more than 2000 µM/kg). Explain why most of the dissolved inorganic carbon in sea-water is in the form of bicarbonate.

TURN OVER

(c) Explain why, for this system, the alkalinity (strictly, the carbonate alkalinity) can be taken to be

$$\textbf{Alkalinity} = \approx [HCO_3^-] + 2[CO_3^{2-}]$$

[Note: remember that by convention the molar concentration of water is taken to be constant and equal to unity].

4) The total dissolved inorganic carbon (DIC) is defined as

$$\sum CO2 = DIC = [H_2CO_3] + [HCO_3^-] + [CO_3^{2-}]$$

(a) Explain why a practical working approximation for oceanic conditions is

$$DIC \approx [HCO_3^-] + [CO_3^{2-}]$$

and derive expressions for the carbonate and bicarbonate ion concentrations as a function of DIC and Alk.

(b) The alkalinity (Alk) of deep sea water is approximately 2400 μM/kg, and the total dissolved inorganic carbon (DIC) is approximately 2300 μM/kg. Using the approximations you have derived, calculate the corresponding concentrations of carbonate and bicarbonate ions.

(c) Biological primary production (mainly by algae) in surface waters decreases DIC by ~ 200 uM/kg, and alkalinity by ~ 150 uM/kg. Estimate the resulting concentrations of carbonate and bicarbonate ions.

(d) If the whole ocean had the composition of surface water, what effect would this have on the calcium carbonate compensation depth ?

(e) Use the diagrams in your handouts to also determine the pH and the pCO_2 for such surface waters.

(f) If, conversely, the surface waters had the composition of deep water, what would the equilibrium pCO_2 of the atmosphere become?

5) Use these results to explain whether, and to what extent,
(a) deep water formation is an important process in the oceanic carbon cycle
(b) enhancement of the biological pump (e.g. by iron fertilisation) is likely to be effective in ameliorating anthropogenic climate change due to CO_2 emissions.