Lecture #23

Dissolved Carbon Dioxide: Open & Closed Systems IV

(Stumm & Morgan, Chapt.4)

Benjamin; Chapter 7
Conservation of Alk, $C_T$

- If you know any 2 of the following, you can calculate the 3rd:
  - Alkalinity
  - pH
  - $C_T$ or $p_{CO_2}$

- Conservative substances
  - Closed Systems
    - Alkalinity & $C_T$
  - Open Systems
    - Alkalinity

To solve these problems requires a high level of precision as Alk is often close in value to $C_T$, and the difference becomes very important.
Alkalinity, $C_T$ and pH

- Three types of problems are covered
  - Adding treatment chemicals to water
    - e.g., Soda Ash, Caustic, chlorine
  - Blending of waters
    - e.g., a surface water with a groundwater
  - Impacts of “internal” processes
    - The photosynthesis problem
- In each we ask about the final pH, Alkalinity and sometimes the $C_T$ or carbonate species
### Addition of Treatment Chemicals

<table>
<thead>
<tr>
<th></th>
<th>pH</th>
<th>$C_T$ (mM)</th>
<th>Alk (meq/L)</th>
<th>Acy (meq/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>6.5</td>
<td>1.7</td>
<td>1</td>
<td>2.4</td>
</tr>
<tr>
<td>“A”</td>
<td>8.3</td>
<td>1.7</td>
<td>1.7</td>
<td>1.7</td>
</tr>
<tr>
<td>A+ 0.7mM NaOH</td>
<td>8.3</td>
<td>1.7</td>
<td>2.4</td>
<td>2.4</td>
</tr>
<tr>
<td>A + 0.7mM Na$_2$CO$_3$</td>
<td>8.3</td>
<td>2.4</td>
<td>2.4</td>
<td>2.4</td>
</tr>
</tbody>
</table>

Assumes a closed system; now determine the composition of each in an open system.
Chlorine problem

- **Starting water**
  - pH=8, Alkalinity = 82.5 mg-CaCO$_3$/L, NH$_3$-N=3.5 mg/L
    - Alk=1.65 meq/L, NH$_3$-N=0.25 mM
- **Use breakpoint chlorination to remove ammonia-N**
  - $2\text{NH}_3 + 3\text{Cl}_2 = \text{N}_2(g) + 6\text{H}^+ + 6\text{Cl}^-$
- **How much NaHCO$_3$ and NaOH must be added to reach pH 9.0 and 2.0 mM C$_T$?**

Snoeyink & Jenkins, example 4-39, pg.188
Deffeyes Diagram

\[ Alk = (\alpha_1 + 2\alpha_2)C_T + [OH^-] - [H^+] \]

- For 15\degree C, closed system (has \( C_T \), not \( p_{CO_2} \))
  - Snoeyink & Jenkins, pg187
  - Stumm & Morgan, pg 177
- Answer to previous problem
  - 0.35 mM NaHCO\(_3\)
  - 0.75 mM NaOH
Nomograph

- Redrawn Deffeyes diagram
  - From Benjamin, 2002
  - Pg. 275
Blending of Waters

- Water A
  - $C_T = 8$ mM
  - Alk = 300 mg/L
  - pH = ?
- Water B
  - $C_T = 4$ mM
  - Alk = 100 mg/L
  - pH ?
- 50/50 Blend
Nomograph

- Redrawn Deffeyes diagram
  - From Benjamin, 2002
  - Pg. 275
More blending problems

- Look at old exams, mostly 2nd exams
  - #2 from 2015
• To next lecture