Wednesday, October 27, 2010

Week 10 Assessment – available thru Friday, Oct. 29, 5 pm

Topic - The Carbon Cycle (Chapter 8)

Marine organic carbon cycle (p 157)
Nutrient limitation (p 158-159)
The biological pump (p 158)
Dissolved inorganic carbon in the ocean (p 162)
Oxidized vs. Reduced Carbon

The oxidation state of carbon refers to the nature of the atoms bonded to that carbon.

The more hydrogens atoms that are attached to carbon the more “reduced” it is

The more oxygen atoms that are attached to carbon the more oxidized it is.

CO$_2$ is a highly oxidized form of carbon

CH$_4$ is a highly reduced form of carbon

To oxidize carbon, one typically only has to add oxygen and burn it (e.g., combustion or respiration)
What is oxidized carbon?

Ans: Carbon atom combined with oxygen – e.g. CO$_2$

What is reduced carbon?

Ans: Carbon atom combined with hydrogen or nitrogen atom.

Both oxidized and reduced carbon can be found in living things, but we call any carbon that is associated with living tissue “organic carbon”. Loosely speaking (and a good ‘guess’), a carbon bonded directly to a “H” atom (e.g., -C-H bond) is (or was) part of a living organism.
Photosynthesis:
- takes oxidized carbon and reduces it (adds hydrogen)

Respiration, decomposition (and combustion):
- Takes reduced carbon and oxidizes it

Respiration and aerobic decomposition:
\[ \text{CH}_2\text{O} + \text{O}_2 \rightarrow \text{CO}_2 + \text{H}_2\text{O} \]

Photosynthesis
\[ \text{CO}_2 + \text{H}_2\text{O} \rightarrow \text{CH}_2\text{O} + \text{O}_2 \]

Inflow:
- 60 Gton(C)/yr
- Respiration and decomposition

Atmospheric
- \( \text{CO}_2 \)
- 760 Gton(C)

Outflow:
- 60 Gton(C)/yr
- Photosynthesis
CO₂ diffuses from high to low concentration (down gradient) – from atmosphere to ocean, if ocean has less CO₂.

CO₂ is soluble in water (‘soda’ or carbonate).

Water holds more CO₂ at lower temperature.

The figure at left shows the amount of fossil-fuel carbon that has diffused into the oceans. We’ll talk about the chemistry next week.
Note – if atmospheric CO$_2$ is increasing over time, the biological pump represents a loss of CO$_2$ from the surface ocean (hence, net removal of CO$_2$ from the atmosphere). This was the mechanism referred to in “Crude.”
Marine Short-term Organic Carbon Cycle

Phytoplankton

Zooplankton

![Phytoplankton images]

![Zooplankton images]

![Graph showing distribution of Organic matter, Oxygen, Nitrate, and Total dissolved C across depth](Copyright © 2004 Pearson Prentice Hall, Inc.)
Marine Short-term Organic Carbon Cycle

Phytoplankton

Zooplankton

Photosynthesis

Decomposition

Deep water formation
Marine Short-term Organic Carbon Cycle

The Biological Pump

Processes:
- Photosynthesis
- Fecal-pellet production
- Oxygen production

Surface ocean:
- \( \text{CO}_2 + \text{H}_2\text{O} \rightarrow \text{CH}_2\text{O} + \text{O}_2 \)

Upwelling of nutrients

Processes:
- Decomposition
- Nutrient release
- Oxygen consumption

Deep ocean:
- \( \text{CH}_2\text{O} + \text{O}_2 \rightarrow \text{CO}_2 + \text{H}_2\text{O} \)

Settling of organic matter
Consider – what happens if thermohaline circulation stops?

(a) The biological pump would shut down
(b) Ocean composition would become more uniform
(c) $\text{CO}_2$ would increase rapidly in the atmosphere
Marine Short-term Organic Carbon Cycle

Photosynthesis produces $O_2$, consumes nutrients

Consumption of $O_2$ and rerelease of nutrients

Decomposition

Deep water formation
So what are the major nutrients (CHNOPS)

Carbon (pretty much available everywhere)

Hydrogen (also plentiful – from water)

Nitrogen (occurs naturally, so tends to be plentiful, but sometimes limited by overconsumption)

Oxygen (usually available – O\(_2\), then as from rocks containing oxygen)

Phosphorus (often bound up in rocks, so tends to be limiting)

Sulfur (in some rocks – also as oxides)
Redfield Ratios

- Named after Alfred C. Redfield
- Findings
  - Carbon: Nitrogen: Phosphorous ratio
    - 106:16:1
  - Same in plankton and seawater
  - Nutrient composition of seawater determined by production and decomposition of organic matter (plankton)
These are the relative amounts of nutrients that are found in phytoplankton, and the things that eat phytoplankton

<table>
<thead>
<tr>
<th>Element</th>
<th>Relative Number of Atoms in Living Phytoplankton</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon</td>
<td>106</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>16</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>1</td>
</tr>
<tr>
<td>Iron</td>
<td>0.01</td>
</tr>
</tbody>
</table>
In which of the following examples is nitrogen the limiting nutrient?

(a) C:N:P = 212:16:2

(b) C:N:P = 212:32:2

(c) C:N:P = 53:8:0.5
In which of the following examples is nitrogen the limiting nutrient?

(a) C:N:P = 212:16:2 = 106:8:1

(b) C:N:P = 212:32:2 = 106:16:1

(c) C:N:P = 53:8:0.5 = 106:16:1