
MATERIALS

- Laptop computer
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BACKGROUND

The carbon cycle (Figure 12-1) is an important biogeochemical cycle. The carbon cycle describes the different reservoirs (rocks, ocean, atmosphere, terrestrial biosphere = soil and plants/animals) in which carbon resides and the different ways carbon moves between these reservoirs. The largest carbon reservoir is found in rocks, but this reservoir is not easily accessible. The smallest carbon reservoir is the atmosphere. Because there is not much carbon in the atmosphere, small changes can have big impacts.

Carbon dioxide (CO_2) is a powerful greenhouse gas, which means that it absorbs outgoing radiation and warms the atmosphere. Over geologic timescales, it has been positively correlated with global temperatures. In other words, the more CO_2 in the atmosphere, the warmer Earth's atmosphere and surface, and CO_2 concentrations have varied considerably over Earth's history. CO_2 is also not the most powerful greenhouse gas; for example, methane (CH_4) is much more powerful. Greenhouse gases are absolutely necessary in Earth's atmosphere to help keep Earth's surface temperatures at levels that are comfortable for living organisms, but we are concerned about CO_2 in the atmosphere today because concentrations have increased considerably since the Industrial Revolution. In this exercise, you will study the CO_2 data set from Mauna Loa, Hawaii, which extends back to the 1950s.

CO_2 is a trace gas in the atmosphere, meaning that the atmosphere has only a small amount of CO_2 compared to other gases such as nitrogen and oxygen, which make up 99% of the atmosphere. Because CO_2 is a trace gas, small changes in the atmospheric reservoir can have big impacts. Commonly the additional CO_2 in the atmosphere since the Industrial Revolution is attributed to human activities such as deforestation and burning fossil fuels. CO_2 concentrations are expressed in units of ppm, or parts per million. For example, today's CO_2 concentrations are around 400 ppm, which means that there are 400 units of CO_2 in one million units of air.



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12

Carbon Dioxide
from the Mauna Loa
Observatory

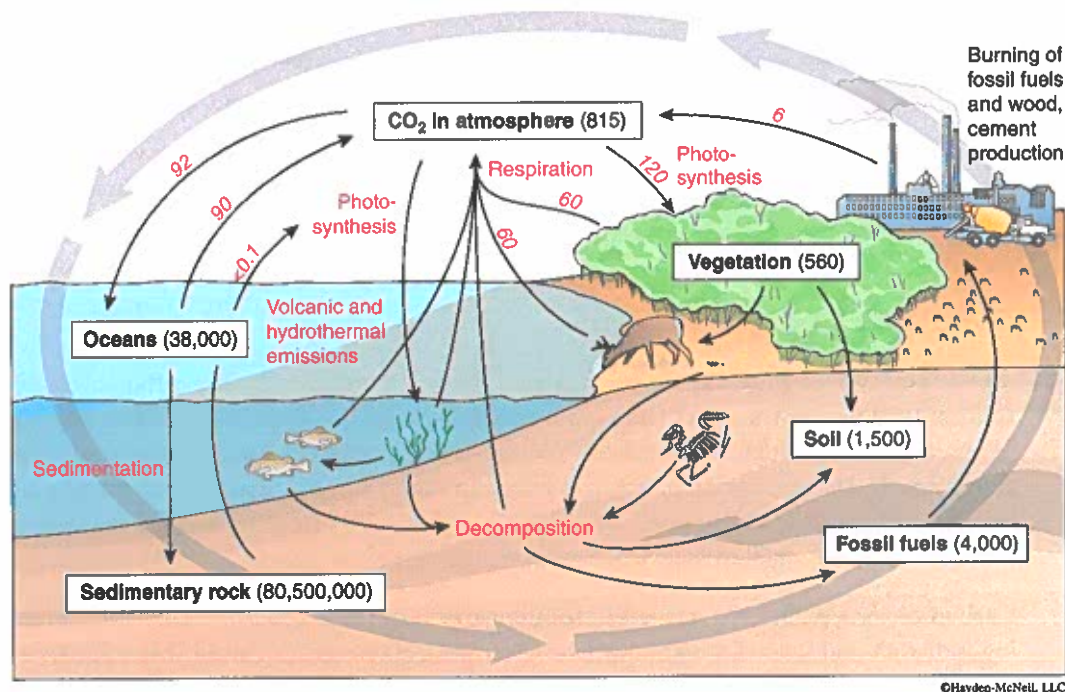


Figure 12-1. *The carbon cycle*

Inquiry Questions to be completed on a separate piece of paper prior to coming to class:

1. How is carbon dioxide related to temperature?
2. How does burning fossil fuels alter the natural carbon cycle?

1 Activity

All data needed for this activity will be provided by your instructor. You are not required to use a specific graphing program for this exercise. You can plot your graphs by hand; however, you will still need to submit the graphs. Note that at the bottom of the opened Excel spreadsheet, there are several different worksheets.

1. From the worksheet titled "raw data," plot the CO₂ concentrations for the months of March during odd years and October during even years. Also, plot the data found in the worksheet titled "random."

2. Using your first (earliest) data point for each graph, estimate the percentage of the atmosphere made up of the trace gas CO_2 . (Hint: $200 \text{ ppm} = 200/1,000,000 = 0.0002$. To get a percentage, $0.0002 \times 100 = 0.02\%$)

Result for March _____ %

Result for October _____ %

Result for Random Data _____ %

3. Now estimate the **slope** of the data to 2 significant digits (e.g., slope = 4.1). To do this you must first find the best-fitting straight line through your data points, and then measure the rise (change in y-axis) over the run (change in x-axis) of this line. Draw the best-fit line on your plot of the data points (you can do this manually or with a computer program—remember the best-fit line does not necessarily pass through the data points). The slope should have units of ppm/year.

Result for March _____ ppm/year

Result for October _____ ppm/year

Result for Random Data _____ ppm/year

4. Compare the three estimates of the slope. Are you surprised (Yes or No) by the comparison between groups? Explain why or why not.

2 Activity

Now you need to estimate how long, based on the rate of increase you determined from your three data sets, it will take for atmospheric CO_2 concentrations to double.

1. At the rate of increase of atmospheric CO_2 concentrations determined in Activity 1 (i.e., with the slope you determined), how many years will it take for CO_2 concentrations to **double** from the value at the beginning of your data? For example, if the beginning value were 300 ppm and the rate of increase were 3 ppm/year, it would take $300/3 = 100$ years to increase by 300 ppm (i.e., double).

Result for March _____ years

Result for October _____ years

Result for Random Data _____ years

2. Commonly when scientists talk about the amount of time to double CO_2 , they are referring to the amount of time to reach 560 ppm. Prior to the Industrial Revolution, atmospheric CO_2 concentrations were 280 ppm. How are your estimates for the time to double impacted by using a different start point?

3. Now plot the data in the worksheet titled "2002–2011" as well as the data in the worksheet titled "1992–2001" (two different graphs). Compare the graphs you created to the provided graph in the worksheet titled "long CO_2 ." What pattern becomes evident in the complete data set for these increments of 10 years? How often does the pattern repeat? What do you think might account for this pattern?

4. Calculate the slope for the two graphs you created. Are the slopes different? If the rate increases in the future, will the time needed to double the atmospheric CO_2 concentration *increase, decrease, or stay the same*? If your slopes are different, that means that the rate of change is not constant. How does this complicate your estimated time to double?

Modified from "Atmospheric CO_2 : How Is It Changing Over Time?" created by Randy Richardson and available on the "On the Cutting Edge" website (<http://serc.carleton.edu/NAGTWorkshops/index.html>)

- CARBON DIOXIDE FROM THE MAUNA LOA OBSERVATORY 131

