Student Sheet 1

MATH APPLICATION ACTIVITY: UNDERSTANDING PPM AND PPB

Carbon dioxide is the primary greenhouse gas emitted through human activities, accounting for about 82% of all U.S. greenhouse gas emissions from human activities in 2013. The continuous measurement of changes in atmospheric CO_2 concentrations was started in March 1958 at the Mauna Loa Observatory, Hawaii by Charles David Keeling and have continued and expanded in scope since then. Concentrations of CO_2 in the atmosphere are increasing at an accelerating rate from decade to decade and research into this trend is ongoing at observatories and research stations around the world.

An atmospheric chemist, studying the components of the atmosphere, is dealing with very tiny number of molecules within a huge sample of air. Sometimes when researching concentrations of GHGs, scientists will talk about concentrations of CO_2 or CH_4 in terms of ***parts per million (ppm)*** or ***parts per billion (ppb)*** because the amounts are so small. For example, a concentration of 1 ppm corresponds to 1 part material per 1 million parts of the gas, liquid or solid it is found in. In the case of ppb, the same relationship exists: 1 part material per 1 billion parts of a gas, liquid or solid.

An easy way to think of ppm is to visualize putting four drops of ink in a 55-gallon barrel of water and mixing it thoroughly. This procedure would produce an ink concentration of 1 ppm. Some other analogies that may help you visualize the scale involved with ppm and ppb: One ppm is like-

- one inch in 16 miles,
- one second in 11.5 days,
- one minute in two years, or
- one car in bumper-to-bumper traffic from Cleveland to San Francisco.

Student Sheet 2

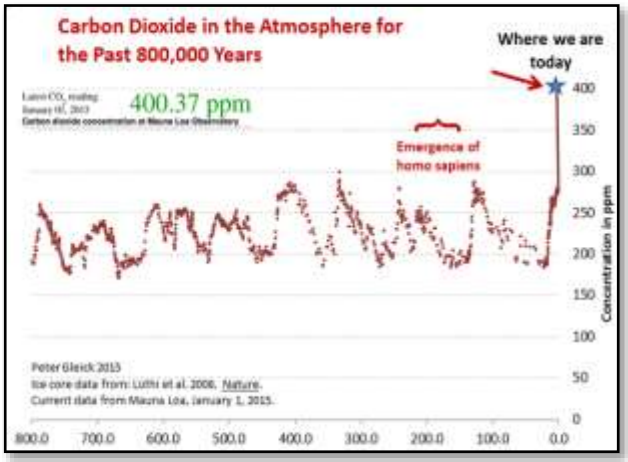
An even smaller concentration measurement, used for methane (CH_4) is parts per billion (ppb). One ppb is one part in 1 billion. One drop of ink in one of the largest tanker trucks used to haul gasoline would be an ink concentration of 1 ppb. Because a ppb is a thousand times smaller than a ppm, other analogies would be:

- one sheet in a roll of toilet paper stretching from New York to London, or
- one pinch of salt in 10 tons of potato chips or
- one second in nearly 32 years.

But just because these amounts are small does not mean that they are not important. Gases like carbon dioxide (CO_2), methane (CH_4) and water vapor (H_2O), as well as several other potent GHGs, are particularly important and have three special characteristics:

- Each is a powerful greenhouse gas and produces positive radiative forcing
- Each exists for a long time in the atmosphere, so that fluctuations in concentration are small when compared to average concentration levels, which tends to warm the surface of the Earth.
- Each has significant anthropogenic (man-made) contributions.

Student Sheet 3



In fact, the increased concentrations of both CO_2 and CH_4 are so powerful that small changes in their concentrations have caused significant increases in the surface temperature of the planet. The global average surface temperature has increased since 1861 and is due, in large part, to an 85 parts-per-million (ppm) increase in carbon dioxide and a 1-ppm increase in methane concentration. These changes are significant and likely to have resulted in the largest temperature change of any century during the past 1,000 years.

ANALYSIS AND COMPREHENSION

1. Record the color of the contents of each cup in **DATA TABLE 1**.
2. In which cup was the color most intense? Why?
3. In which cup is the color least intense? Why?
4. a. Are there any cups in which the liquid is colorless? b. Is there any food coloring in these cups? c. How do you know?
5. Cup #1 contains food coloring and no water added. What is the percent concentration of the food coloring in Cup #1?
6. One hundred percent (100%) can be written 100/100. Complete the following fraction so that both are equal: 100/100 = ________ /1,000,000
7. The concentration of food coloring in Cup #1 is 1,000,000 ppm or 1 million parts per million. Using this information complete the **CONCENTRATION** row of **DATA TABLE 2**. Convert the ppms to ppbs and identify the cups.

Student Sheet 4

8. Earth's atmosphere contains 78% nitrogen (N) and 21% oxygen (O). Write these percentage as concentrations in ppm:

   a. 78% = ______/100 = _______________/1,000,000=_______ppm

   b. 21%= ______/100 = _______________/ 1,000,000= _______ppm

9. Carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and CFCs are gases, which affect the temperature of the atmosphere. Their concentrations are listed in **DATA TABLE 2**. Which of the cups of coloring is closest in concentration to the concentration of each gas?

10. How does the concentration of greenhouse gases compare to the concentration of oxygen and nitrogen?

11. At what concentration did you notice that the color of the drink mix was no longer visible?

12. How can such small concentrations of gases like CO_2 and CH_4 have such a large effect on our atmosphere?

13. Illustrate a slice of the atmosphere indicating the concentrations of each of the various gases listed in **DATA TABLE 3**. Make a graph, chart, picture, or drawing. Represent the gases of the atmosphere in their ppm.

14. Complete the missing information in **DATA TABLE 4**.

Student Sheet 5

DATA TABLE 1

CUP #	1	2	3	4	5	6	7
COLOR							
PPM							

DATA TABLE 2

GAS	CONCENTRATION	CUP #
CO_2	355 ppm=_________________ ppb	
CH_4	1.7 ppm =________________ ppb	
N_2O	0.3 ppm=_________________ ppb	
CFC-11	.0003 ppm= _____________ ppb	
CFC-12	.0005 ppm =_____________ ppb	

DATA TABLE 3

GAS	CONCENTRATION PPM
Nitrogen	780,000
Oxygen	210,000
Water vapor	40,000
Argon	10,000
Neon	8
Helium	5
Methane	1.7
Ozone	0.1
CFCs	.0006
Carbon dioxide	345

Student Sheet 6

DATA TABLE 4: CONCENTRATIONS OF ATMOSPHERIC GASES

*Concentrations vary

Gas	Decimal Fraction	Percent	PPM	PPB
Nitrogen	0.78	78.0	780,000	780,000,000
Oxygen		20.95		
Argon		0.93		
Neon		0.0018		
Helium		0.00052		
Hydrogen		0.00005		
*Water vapor		0.04		
*Ozone	.	0.000003		
*Methane		0.000175		
*Carbon dioxide		0.0400		
*Nitrous oxide		0.00003		
*CFCs (Total)		0.0000035		