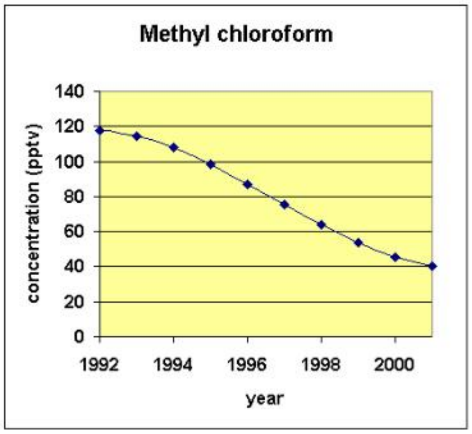
Global Pollution

The water bucket model at
http://cs.clark.edu/~mac/physlets/GlobalPollution/WaterB2.htm
is also a good model of global pollution.

The link http://cs.clark.edu/~mac/physlets/GlobalPollution/TraceGasTheory.htm
Has background definitions, theory, a modified model, and on-line model that you can use to answer the questions here.

No emission source of pollution



Example from the real world. Methyl chloroform is a source of stratospheric chlorine which is linked to ozone depletion. After the Copenhagen amendment to the Montreal protocol in 1992, emissions of methyl chloroform into the atmosphere dropped very rapidly to nearly zero. ***Data source: ALE / GAGE / AGAGE Network (updated and revised February 2002), DB-1001 (an Internet-accessible numerical database) http://earthtrends.wri.org/text/CLI/variables/84.htm***

The objectives of the questions below are to:

- Familiarize students with basic terms from atmospheric chemistry and global pollution: *Emission Source, Atmospheric Life-time, Atmospheric Concentration, equilibrium concentration, growth rate, removal rate.*
- Use a model of global pollution to understand the interrelations between these key variables.
- Calculate equilibrium concentration from source emission strength and lifetime.
- Sketch the dynamic behavior using the concept of half-life and equilibrium concentration.

Model of global pollution

Zero emission Source, So=0 for a hypothetical trace gas.

Q1: Start with Co=100 ppm, lifetime=10 yrs, So=0, and R=0. What is the concentration in a time of one lifetime (10 years in this case) after the run starts? =_____________

Q2: How long does it take the concentration to drop to half its starting value?
=___________________ *(Mouse click and hold allows you to read numbers from graph).*

Q3: How does this "half-life" time compare to the atmospheric lifetime? That is, what is the ratio of half-life divided by lifetime? =_________________

Q4: Repeat Q1 through Q3 for Co=100 ppm, lifetime=20 yrs, So=0, and R=0. Use the Run 2 button for this so it can be compared with the 10 year lifetime simulation.

Concentration in a time of one lifetime =__________________

Time for concentration to drop to half its starting value (half-life)=_______________

ratio of half-life divided by lifetime=____________

Q5: Repeat Q1 through Q3 for Co=100 ppm, life-time=40 yrs, So=0, and R=0. Use Run 3 button for this simulation.
Concentration in a time of one lifetime =__________________

Time for concentration to drop to half its starting value (half-life)=_______________

ratio of half-life divided by lifetime=____________

Summarize your results in this table.

Questions	lifetime (yrs)	Concentration at t=lifetime	Half-life	ratio
Q1-Q3				
Q4				
Q5				

Q6: For a given initial concentration, is the concentration one lifetime after starting the run always the same regardless of what the value of the lifetime is?

Q7: Is the half-life divided by the lifetime always the same?
What are your three ratio values from Q3, Q4, and Q5?

Q8: Using a lifetime of 20 yrs, estimate the half-life for runs starting with Co=100 ppm, 80 ppm, 60 ppm, 40 ppm, and 20 ppm.

Co (ppm)	Half-life
100	
80	
60	
40	
20	

Q9: Does the half-life (or life-time) depend on the initial concentration?

Fixed emission Source So=constant R=0 (for al questions here and below assume that the source emission is constant, i.e. R=0)

Q10: Starting with Co=100ppm, what is the equilibrium concentration when S=4.0ppm/yr and lifetime equals 10.0years?

Q11: Repeat Question 10 for initial concentrations Co=80ppm, 60ppm, 40ppm, and 20ppm, using So=4.0ppm/yr and life-time=10years.

Co (ppm)	C_{eq} (ppm)
100	
80	
60	
40	
20	

Q12: Does the equilibrium concentration depend on the initial concentration?

Q13: For Co=0, lifetime=10 yrs, and R=0.0 find the equilibrium concentration for S= 2, 4, 6, 8, and 10 ppm/yr.

S (ppm/yr)	C_{eq} (ppm)
2	
4	
6	
8	
10	

Q14: Does the equilibrium concentration depend on the emission source strength? How does doubling S from 2 to 4 ppm/yr influence the equilibrium concentration?

How does quadrupling S from 2 to 8 ppm/yr influence the equilibrium concentration?

Q15: For Co=0, S=4 ppm/yr, and R=0.0 find the equilibrium concentration for lifetimes of= 2.5, 5, 10, 20, and 25 years.

lifetime (yrs)	C_{eq} (ppm)
2.5	
5	
10	
20	
25	

Q16: Does the equilibrium concentration depend on the emission lifetime?
How does doubling lifetime from 2.5 to 5 years influence the equilibrium concentration?

How does a ten fold increase in lifetime from 2.5 to 25 years influence the equilibrium concentration?

Q17:Which of these equations best describes the equilibrium content?
a. Ceq=S*(lifetime)
b. Ceq=(lifetime)/S
c. Ceq=S/(lifetime)
d. Ceq=S + (lifetime)

Part II. Dynamic Behavior of pollutants.
Knowing the lifetime and source strength make it easy to calculate the equilibrium concentration of a trace gas pollutant. However if you want to make a graphical sketch of the concentration varies over time the half-life is easier to use.

On the model page http://cs.clark.edu/~mac/physlets/GlobalPollution/Lifetime3.htm scroll down to the down to questions link and then to the A bit of info for part II link below the text box. After looking this over scroll back up to the model area to proceed.

Q18: The initial concentration is 100ppm and the atmospheric half-life of a gas is 10 years, (life-time=14.44 years). Fill in the table below assuming that there are no emission sources after time=0.

Initial concentration =100 ppm, S=0, and half-life =10 years

time (yrs)	C (ppmv)
0	100
10	
20	
30	
40	
50	
60	

Check your results by running the model. Remember to use life-time as model input NOT half-life.

For Q19 & Q20 assume that the initial concentration is 0.0, the emission source S is constant at 7.0 ppm/yr and the half-life of a gas is 10 years (life-time t=14.44 years).
Q19: For this case what is the equilibrium concentration?
Ceq = ____________________

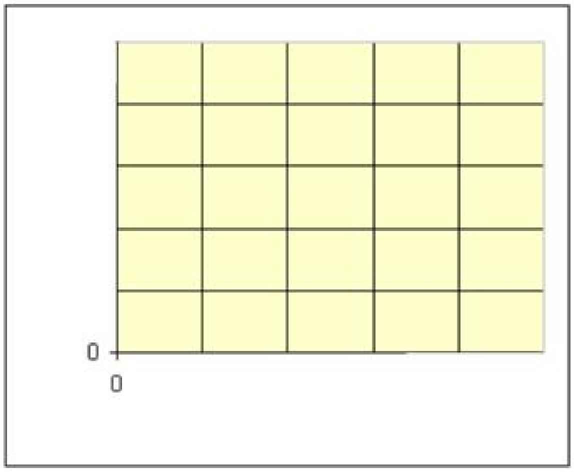
Q20: Complete the table below assuming that S=7.0 ppm/yr.
Remember that the half-life is the time required for the gap between the concentration at any instant and the equilibrium concentration to cut in half. So for this case the initial gap between the starting concentration (0 ppm) and the equilibrium concentration (100 ppm) is 100 ppm. The gap reduces in the same way that the concentration dropped in the above example. The concentration at any time is C=Ceq-gap=100-gap.
That is when the gap has narrowed to 20 ppm the concentration has gone up to 80 ppm.

Initial concentration =0 ppm, S=7 ppm/yr, and half-life =10 years

time (yrs)	gap(ppmv)	C(ppmv)
0	100	0
10		
20		
30		
40		
50		
60		

Check your results by running the model.

Q21: For times between 0 and 50 years, Sketch a graph of the concentration on y-axis vs. time on the x-axis for lifetime=14.44 yrs, initial concentration =0.0, and emission source=5 ppm/yr. If you need to you can use the model.



Q22: For times between 0 and 50 years, Sketch a graph of the concentration on y-axis vs. time on the x-axis for lifetime=28.88 yrs, initial concentration =50.0, and emission source=5 ppm/yr.