Box Model equation: $$q = \frac{S * \tau}{V}$$

1. The emissions rate of NO in downtown Metropolis is 5.8×10^{27} molecules of NO per day. If the lifetime of NO in downtown is ¼ day, calculate the concentration (molecules/cm^3) of NO in the downtown area. Use a volume of 4.7×10^{16} cm^3**.**

S = 5.8×10^{27} molecules NO/day
V = volume of the basin = 4.7×10^{16} cm^3
τ = 1/4 day

We can now calculate the concentration of NO by applying the above formula:

$$q = \frac{S * \tau}{v} = \frac{\left(5.8\times10^{27}\ \frac{molecules\ NO}{day}\right) * \left(\frac{1}{4}\ day\right)}{\left(4.7\times10^{16}\ cm^3\right)} = 3.09\times10^{10}\ \frac{molecules\ NO}{cm^3}$$

2. Convert your answer from #3 to a mixing ratio (ppbv). Assume that 1 cm^3 of air contains 2.5×10^{19} molecules.

$$Mixing\ Ratio = \frac{Concentration}{AirDensity} = \frac{3.09\times10^{10}\ \frac{molecules\ NO}{cm^3}}{2.5\times10^{19}\ \frac{molecules\ air}{cm^3}} = 1.23\times10^{-9}\ \frac{molecules\ NO}{molecule\ air} = 1.23\ ppbv\ NO$$

3. The city of Metropolis has an approximate volume of 1.5×10^{18} cm^3. The total SO_2 emissions in that basin are 1×10^{30} molecules of SO_2 per day and the residence time of SO_2 is ½ a day. What is the concentration in molecules/cm^3 of SO_2 in the city?

S = 1×10^{30} molecules SO_2/day
V = volume of the basin = 1.875×10^{18} cm^3
τ = 1/2 day

We can now calculate the concentration of SO_2 by applying the above formula:

$$q = \frac{S * \tau}{v} = \frac{\left(1\times10^{30}\ \frac{molecules\ SO_2}{day}\right) * \left(\frac{1}{2}\ day\right)}{\left(1.5\times10^{18}\ cm^3\right)} = 3.33\times10^{11}\ \frac{molecules\ SO_2}{cm^3}$$

4. The mixing ratio of carbon monoxide in Metropolis is 300 ppb. What is its concentration in molecules/cm^3? Remember that 1 cm^3 of air contains 2.5×10^{19} molecules, and that 1 ppb means "one part per billion" (billion=10^9).

300 ppbv of CO means 300 molecules of CO in 10^9 molecules of air (M.R.=$300x10^{-9}$). Given that there are $2.5x10^{19}$ molecules of air per cm^3 and we know that:

Concentration=Mixing Ratio * Air Density

$$Concentration = 300\times10^{-9}\ \frac{molecules\ CO}{molecule\ air} * 2.5\times10^{19}\ \frac{molecules\ air}{cm^3} = 7.5\times10^{12}\ \frac{molecules\ CO}{cm^3}$$

5. Let's assume that the residence time, τ, of carbon monoxide in the Metropolis basin is 1 day and that 14 Million people live in the basin. How many CO molecules does each person emit per day? The volume of the basin is 1.875×10^{18} cm^3**.**

To solve this question transform the steady state box model equation to calculate the source rate, S, from the concentration, q, the volume V, and the residence time τ.

$$q = \frac{S*\tau}{V} \quad \Rightarrow \quad S = \frac{q*V}{\tau}$$

q = CO concentration = 7.5×10^{12} molecules/cm^3
V = volume of the basin = 1.875×10^{18} cm^3
τ = 1 day
We can now calculate the source rate of CO by applying the above formula:

$$S = \frac{q*V}{\tau} = \frac{\left(7.5\times10^{12}\ \frac{molecules\ CO}{cm^3}\right) * \left(1.875\times10^{18}\ cm^3\right)}{(1\ day)} = 1.4\times10^{31}\ \frac{molecules\ CO}{day}$$

Each person the emits: s = S/population = (1.4×10^{31} molecules CO/day)/(1.4×10^{7} persons) =1×10^{24} molecules CO/day per person